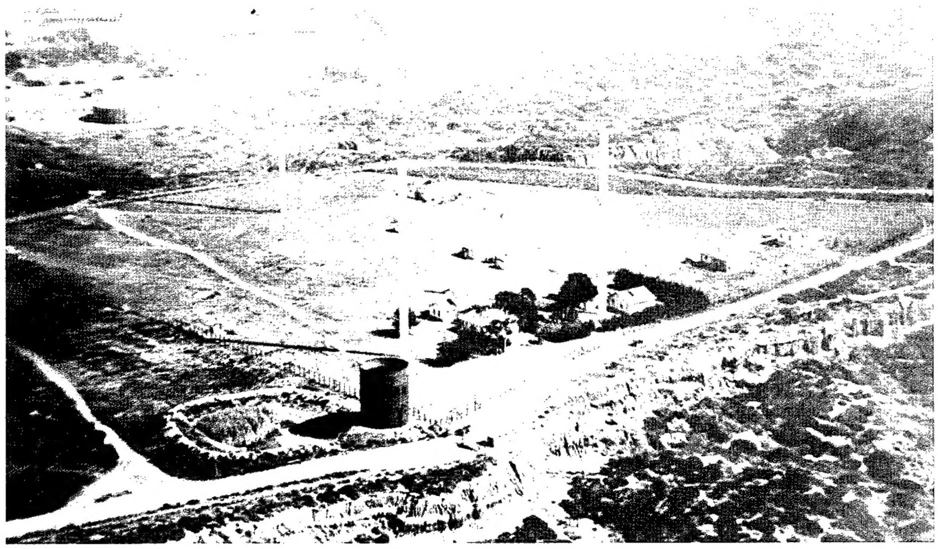
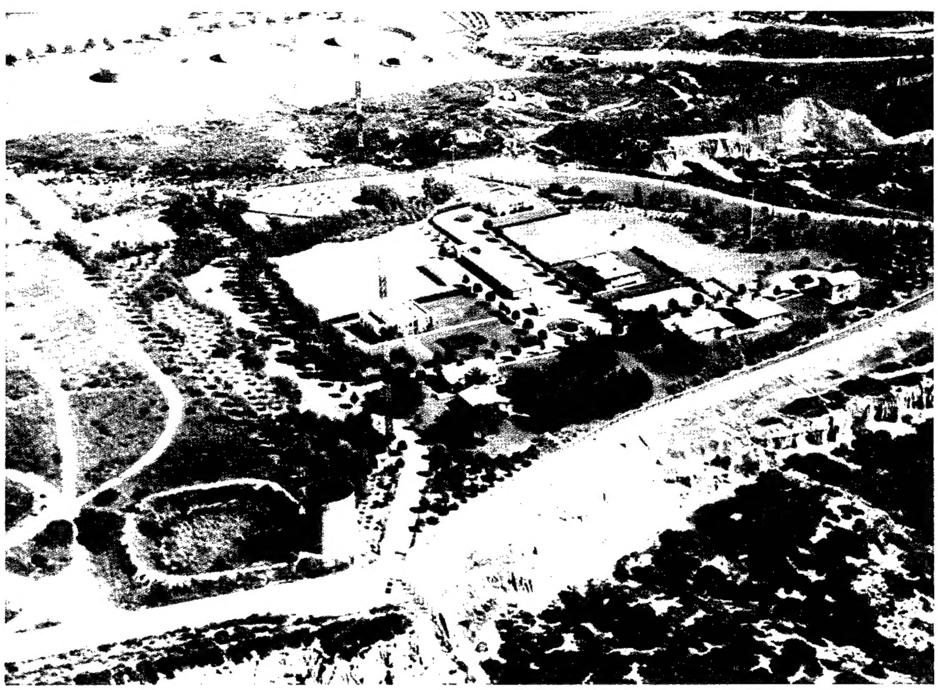
FIFTY YEARS OF RESEARCH AND DEVELOPMENT ON POINT LOMA

1940-1990



Navy Radio Station, Point Loma, 1924. View to southeast. Station in center.



Navy Radio Station, Point Loma, 1934. View to southeast.

Acknowledgment

Much of the information in this book was based on the research and documentation of Dr. Mark Jacobsen, Center Historian at NOSC from June 1985 to September 1988 and now an employee of the U.S. Naval Historical Center. Dr. Jacobsen's substantial effort and continued assistance is greatly appreciated.

Foreword

This brief history marks the 50th anniversary of the Naval Ocean Systems Center (NOSC) and its predecessor organizations. Its purpose is to recognize and highlight 50 years of contribution by NOSC's people to our fighting forces, afloat and ashore, our Navy, and our country.

NOSC has grown from a small applied research laboratory to a full-scale Research and Development Center with advanced and sophisticated laboratory and test facilities. But the real fabric of the Center has been its talented and dedicated people, today numbering more than 3000, over half of whom are scientists and engineers.

There is no better recognition of our people than to highlight some of their accomplishments. Many systems that the Navy now depends upon have their foundations at NOSC: almost all Navy communications systems—including virtually all of the satellite communications systems; command and control systems ashore and afloat; all lightweight torpedoes, their fire control systems, and stand-off delivery systems; most of the Navy's operational undersea, unmanned vehicles; and virtually all of the Navy's undersea surveillance systems. The Center has also continually introduced advanced technology into the Fleet, including advanced electronics—especially microelectronics, acoustics, radar applications, signal and image processing, and computer science.

This history highlights these and other accomplishments. It shows the evolution of research and development at the Center and recognizes and emphasizes the quality of the people who have made it all work. In a brief history, it is not possible to give all projects and people their due. Specific programs highlighted are meant to be typical of the accomplishments for the times indicated.

As we approach the 21st century, NOSC continues to have dedicated and talented people. For 50 years, this Center has contributed to our Navy. Given the excellent people we have today, both technical and support, that level of contribution will continue through the next 50 years and beyond.

R M Hillyer

Robert M. Hillyer
Technical Director
Naval Ocean Systems Center

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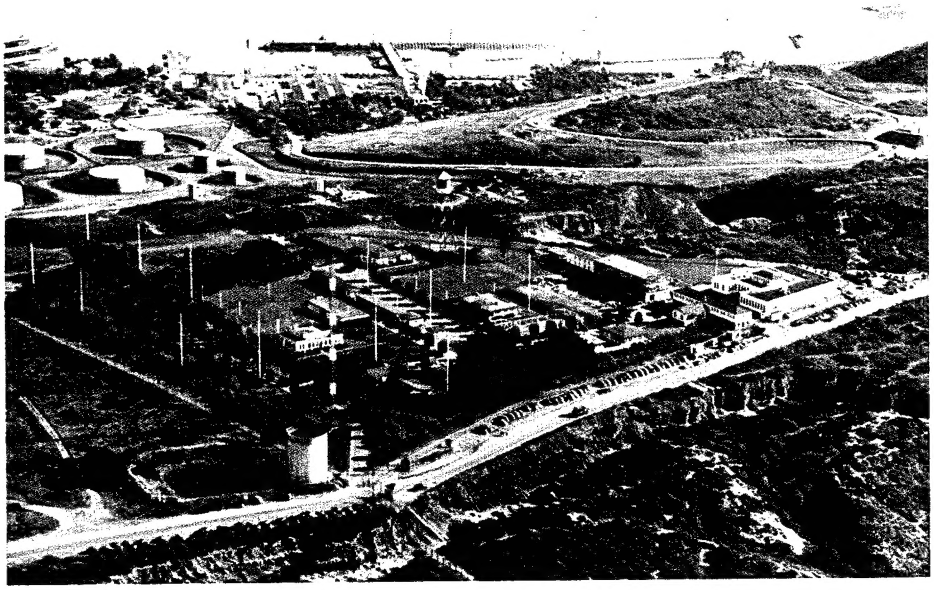
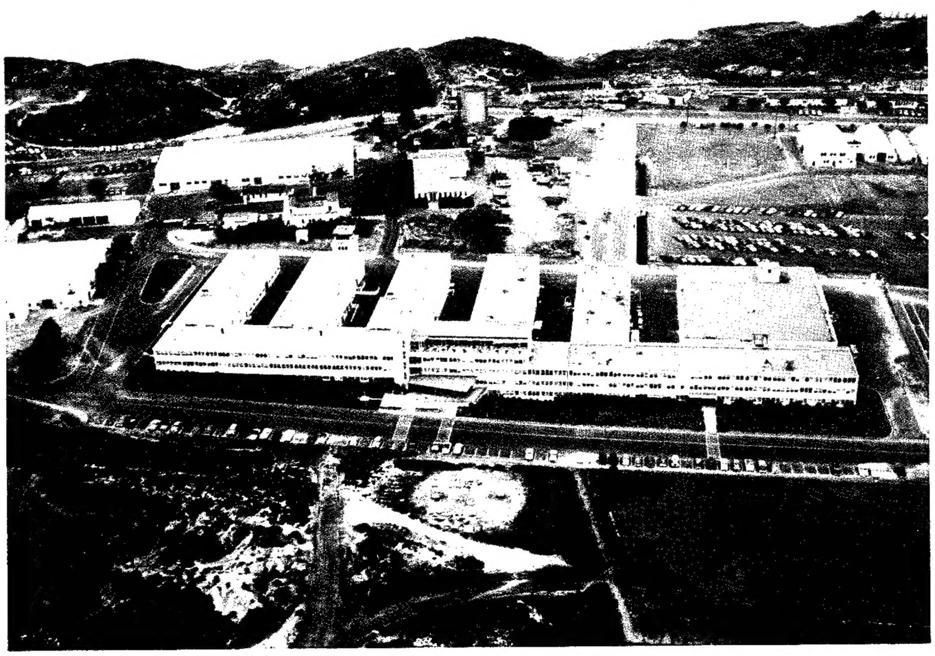


Navy Radio Station, Point Loma and Navy Radio and Sound Laboratory, 1942. View to southeast. Building 2 under construction at right center.



Navy Electronics Laboratory, 1954. View to west. Building 33 in center.

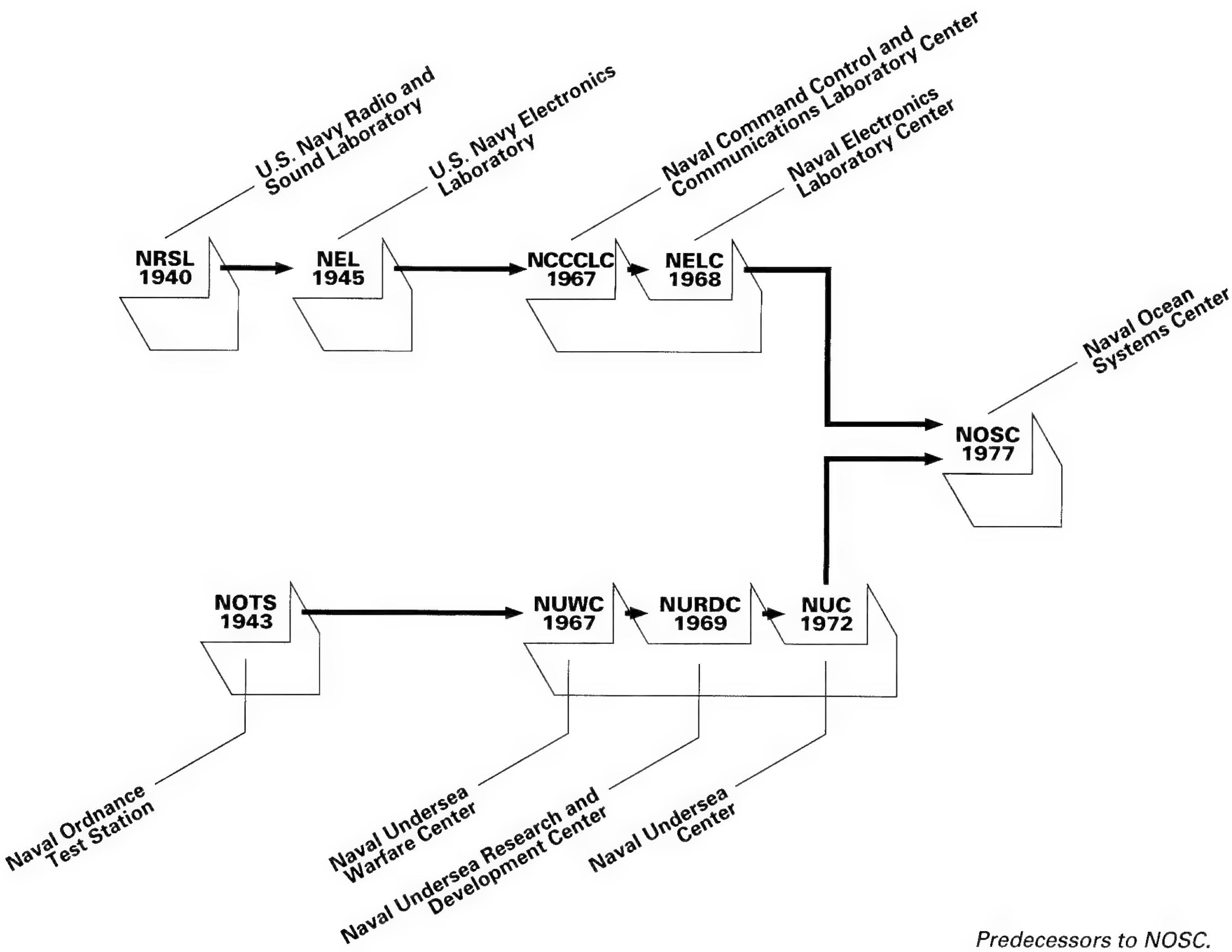
Overview

The Naval Ocean Systems Center (NOSC) in San Diego was formed in 1977 by the merger of two separate Navy laboratories: the Naval Electronics Laboratory Center (NELC) and the Naval Undersea Center (NUC). The history of NOSC, however, embraces the separate histories of these two predecessor organizations, and in turn, the histories of their predecessors. Part of NOSC traces its ancestry back to 1940 when the U.S. Navy Radio and Sound Laboratory (NRSL) was established at San Diego, and part traces its ancestry to 1943 with the establishment of the Naval Ordnance Test Station (NOTS) at Inyokern, CA, in the high desert country northwest of the Mojave Desert.

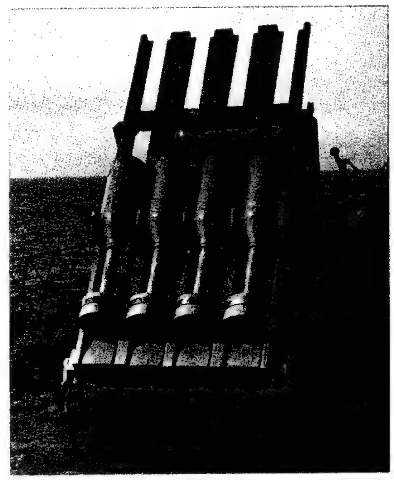
While NOSC has had various names over the years, a history of a working laboratory is more than a history of its name changes. This short history discusses the events, the policies, and the people that have influenced the laboratory and its products. It examines the effects, issues, and motivations that shaped NOSC's work as we know it today.

Specific projects undertaken at this Center have taken place against a background of technological progress. During the period covered by this history, computers, for example, progressed from costly room-sized mainframes to inexpensive microcomputers offering much greater computing power. During the 1950s, when few computers were available, NOSC scientists built their computers and developed programming languages. Three decades later, these scientists and engineers have far more computing power on their desks in "personal computers" than they once had in mainframes. In addition, they can now work with new-architecture supercomputers able to solve problems that were previously thought unsolvable.

This history highlights projects that exemplify many programs and the work of many people. Foremost among these projects have been those dealing with antisubmarine warfare, radio communication, navigation, command control, oceanography, and arctic submarine operations. Not all projects begun at NOSC have led to new operational systems such as those described here. Much of the work of Navy laboratories has consisted of "quick fixes," emergency modifications to systems and electronic devices to solve a particular problem, to extend an existing capability, or to make the system work in a new enviornment. Such work seldom is well-known, but it wins the gratitude of the Navy and its personnel, whose success and whose lives can depend on such results.



Predecessors to NOSC.



Introduction

During the World War II era, the Navy presence on the Point Loma peninsula of San Diego grew from a small radio station to an established research facility. Founded in 1940, the Navy Radio and Sound Laboratory (NRSL) worked to improve radar, radio transmission and reception, and sonar. NRSL's success with the design and arrangement of ship antennas eventually led NRSL to an ongoing mission for antenna development.

While technical advances in the electronics and radio field had opened the way for the use of sonar, this new technology required operational testing before it could be reliably used by the Navy. In 1941, the University of California Division of War Research (UCDWR) contracted to perform sonar research at the NRSL facility in San Diego. UCDWR also performed basic research in oceanography and provided field engineering support to U.S. submarines. UCDWR developed the QLA, an FM high-definition sonar system that enabled U.S. submarines to penetrate the heavily mined Japanese Inland Sea and effectively sever communications between the five main Japanese islands. UCDWR also developed the NAC and NAD Sound Beacons (sound decoy devices for submarines) and "racons" (small radar beacons used to assist in navigation).

Prior to the establishment of the Naval Ordnance Test Station (NOTS) at Inyokern in the northwestern part of California's Mojave Desert, the California Institute of Technology (Caltech) in Pasadena managed wartime research that included modifying and testing air-dropped torpedoes. Caltech's ring-tailed torpedo was accepted by the Fleet in 1944 and paid off in tremendous victories by Navy aviators at the Battle of Leyte Gulf.

The success of efforts in San Diego and Pasadena helped establish the value of military research and development (R&D). As the nation moved into the postwar era, it was agreed that continued military R&D was vital to national defense.

Scientists and National Defense

National Academy of Sciences

After the collapse of France in June 1940, scientists affiliated with the National Academy of Sciences in Washington recognized that the nation's scientific talent would have to be mobilized for national defense. As a privately funded advisory organization, the Academy could not itself direct the scientific effort, but because of its close contacts with the government and higher education, the Academy could galvanize political opinion in Washington and scientific opinion within universities.

National Defense Research Committee (NDRC)

During World War I, the Academy had organized the National Research Council to coordinate science on behalf of the war effort. In 1940, leaders of the Academy, including physicist Dr. Vannevar Bush, then president of the Carnegie Foundation, thought that a similar organization could play a key role in the present national emergency and approached President Franklin D. Roosevelt. Roosevelt agreed, and in June, established the National Defense Research Committee (NDRC) with Bush as its chairman and its membership drawn from the Academy.

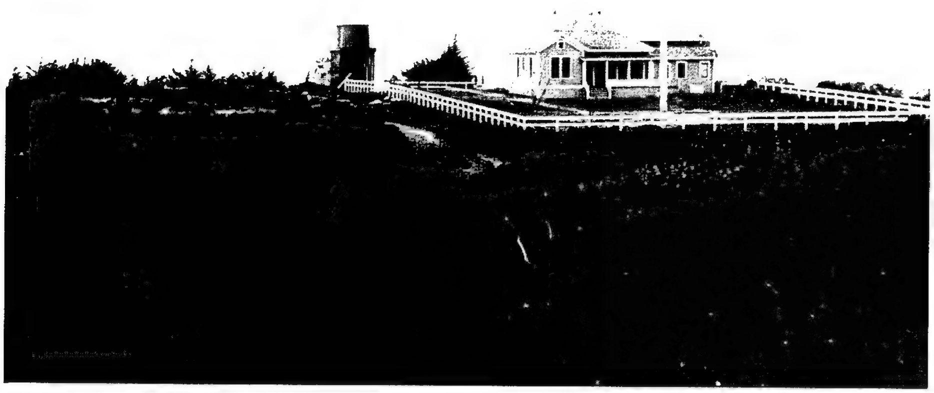
Because NDRC originated the laboratories that eventually formed NOSC, it is worth examining what NDRC sought to accomplish. Bush and his colleagues agreed that NDRC's function would be to direct basic research, not to manufacture military hardware. The Army and Navy would remain responsible for purely military R&D. Bush and his colleagues recognized that the international situation required that NDRC draw upon existing laboratories, private and public. NDRC questioned the Army and Navy on their current research and needs. NDRC also wrote to 725 colleges and universities nationwide to obtain information about their staffs and facilities that might be used for military research. The University of California responded in January 1941 by forming a Defense Council under the chairmanship of the university's president, Robert Sproul, to coordinate all war-related research on the university's two campuses (Los Angeles and Berkeley).

Navy Radio and Sound Laboratory (NRSL)

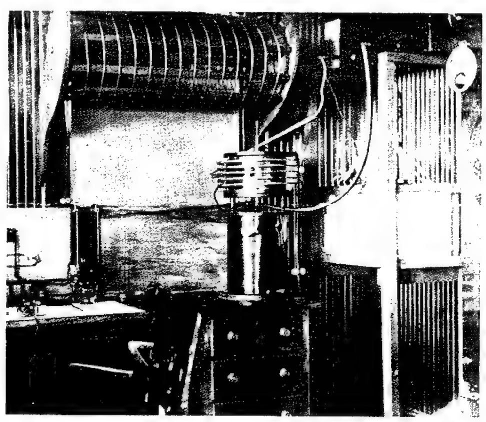
Recognizing the importance of new technologies and the need for technical expertise, the Navy in 1939 established a sound school in San Diego to train sonar operators. The approach of war in Europe and Asia, however, strengthened the case for the Navy to do more research and development. In May 1939, the Chief of the Navy's Bureau of Engineering (BuEng) recommended to the Chief of Naval Operations (CNO), Admiral Harold Stark, that a radio laboratory be established on Point Loma to coordinate the Navy's research and development in communications and radio propagation. On 1 June 1940, the newly appointed Secretary of the Navy, Frank Knox, formally established the U.S. Navy Radio and Sound Laboratory (NRSL)—the Navy's first laboratory on the West Coast. The location atop Point Loma was optimal for experimental work in radio propagation and reception. Also, NRSL's closeness to the Pacific Fleet meant the laboratory could readily support fleet needs. Initial personnel at NRSL consisted of nine enlisted men, three civilians, and one officer-in-charge.

Navy Radio Station, Point Loma

Navy activity on Point Loma actually began with the commissioning in 1906 of the Navy Radio Station, Point Loma. The Radio Station, part of the Navy's very low frequency (VLF) communications network, operated for more than 40 years. On several occasions, NPL (also the station's call letters) participated in experiments, but the station was a transmitting facility, not a laboratory. On the eve of World War II, the Radio Station comprised a handful of small wooden buildings staffed by two radio engineers, two enlisted men, a secretary, and an officer-in-charge. The Radio Station continued to operate until 24 June 1949, when it was decommissioned, and its activities were shifted to a new station at Chollas Heights, an area of San Diego approximately 15 miles southeast of Point Loma.



Navy Radio Station, Point Loma, at time of commissioning. View to northeast. The road at the left of the fence became Catalina Boulevard.



A Massie Wireless Telegraph Company, 5-kilowatt transmitter was installed at the Radio Station in 1906.

University of California Division of War Research (UCDWR)

When German U-boats began sinking merchant and passenger ships without warning in 1939 the Navy sought an independent review of its capabilities to meet this threat and turned to the National Academy of Sciences. In the autumn of 1940, the Academy appointed a Subcommittee on Submarine Detection to study the problem. The Subcommittee reported in January 1941 that the Navy's methods had hardly progressed since 1918, largely because of the "altogether inadequate research effort on fundamentals...." The Navy had made progress in echo-ranging (the forerunner of active sonars), but a broader research thrust including audible and subsonic frequencies was necessary. To remedy this, the Subcommittee recommended that the Navy research program be broadened to include the development of instruments to measure and record underwater phenomena. In addition, the Navy would have to train more ship sound operators, since submarine detection technology had outpaced the Navy's training facilities.

Expanding research and training programs would require added facilities, and the Subcommittee suggested a new laboratory. NDRC recommended two new laboratories, one on each coast, near existing naval bases to facilitate interaction with the Navy. San Diego offered unique advantages as a site for underwater warfare research: (1) deep ocean was close; (2) the oceanography of the California coast had already been studied extensively by the nearby Scripps Institution of Oceanography; (3) the Navy had an existing sound school in San Diego for training sonar operators; and (4) the Federal Government already owned most of Point Loma.

With the Navy's support, NDRC accordingly decided to establish two laboratories, one on the East Coast at New London, Connecticut, and the other at San Diego. After negotiations with NDRC, the University of California, on 26 April 1941, formally established a Division of War Research (UCDWR) to administer the new laboratory in San Diego. UCDWR was sited on the grounds of NRSL. The combined establishment was known as "UCDWR at the U.S. Navy Radio and Sound Laboratory." Informally, the Navy knew it as the "San Diego Laboratory." (Further references in this history to the San Diego Laboratory will mean the combined establishment of NRSL/UCDWR.)

Coordinating Scientific Research for War

Vannevar Bush had noted in December 1940, in a secret report to Roosevelt, that the U.S. lagged seriously in applying scientific knowledge to military devices and systems. Bush recommended an organization to administer all scientific research related to national defense. Once again, his suggestion was accepted, and on 28 June 1941, President Roosevelt signed an executive order creating the Office of Scientific Research and Development (OSRD) with Bush as director. OSRD incorporated NDRC as an advisory council and took over management of its contracts. During World War II, OSRD (disbanded in 1946) oversaw innumerable R&D projects at many locations nationwide. Work ranged from tropical medicine to radar and from proximity fuses for antiaircraft shells to the atomic bomb.

In California, OSRD contracted with the University of California at Los Angeles (UCLA) to manage the San Diego Laboratory while the Navy paid for most of the R&D costs. OSRD also contracted with the California Institute of Technology (Caltech) in Pasadena to conduct research in rocket propulsion and underwater ordnance. From these wartime beginnings grew the Navy laboratories that today form NOSC.

The Growth of a Laboratory

Personnel

Although most of the facilities on Point Loma were Navy, most of the workers at the San Diego Laboratory were employed by the University of California, not by the Navy. At its wartime peak, NRSL had a staff of about 150 civilians, while UCDWR's staff numbered approximately 575.

Radar and radio experts were transferred to NRSL from the Naval Research Laboratory (NRL) in Washington, D.C.; Navy officers and petty officers were called back from retirement to serve at NRSL.

Dr. Roger Revelle was a Lieutenant, USNR, at NRSL. He later became a Director of Scripps Institution of Oceanography, a founding father of the University of California at San Diego (UCSD), and the person for whom Revelle College at UCSD was named.

Dr. Vern Knudsen came from UCLA to be the first head of UCDWR. Dr. H. U. Sverdrup, then Director of Scripps, left Scripps to work at UCDWR. Other scientists were recruited from universities and private industry. Dr. C. F. Eyring came from Brigham Young University in Utah where he was one of the few experts on underwater sound. He brought with him one of his new Ph.D.s, Dr. Ralph Christensen, who later became Technical Director of the San Diego Laboratory from 1960-1968 when it was known as the Navy Electronics Laboratory (NEL) and then the Naval Electronics Laboratory Center (NELC). Many others came to Point Loma in the early years and continued their association in important roles later in the Laboratory's history.

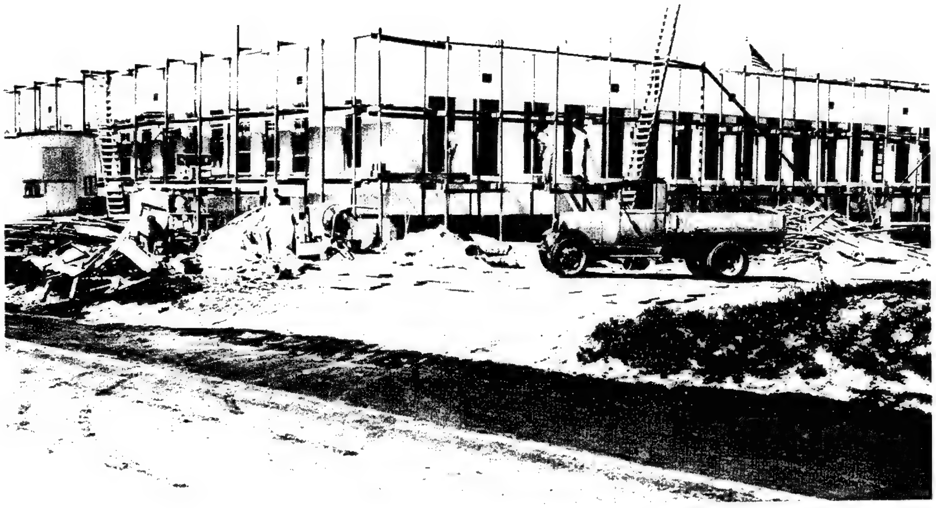
Also during the early 1940s, almost the only people who knew about electrical recording and projecting of sound were in the movie industry. Several people were recruited from Hollywood. Arthur Roshon, who was a key figure in the development of both the QLA mine-avoidance sonar and the first ice-piloting sonars (discussed later in this history), came from the Walt Disney studio.

Facilities

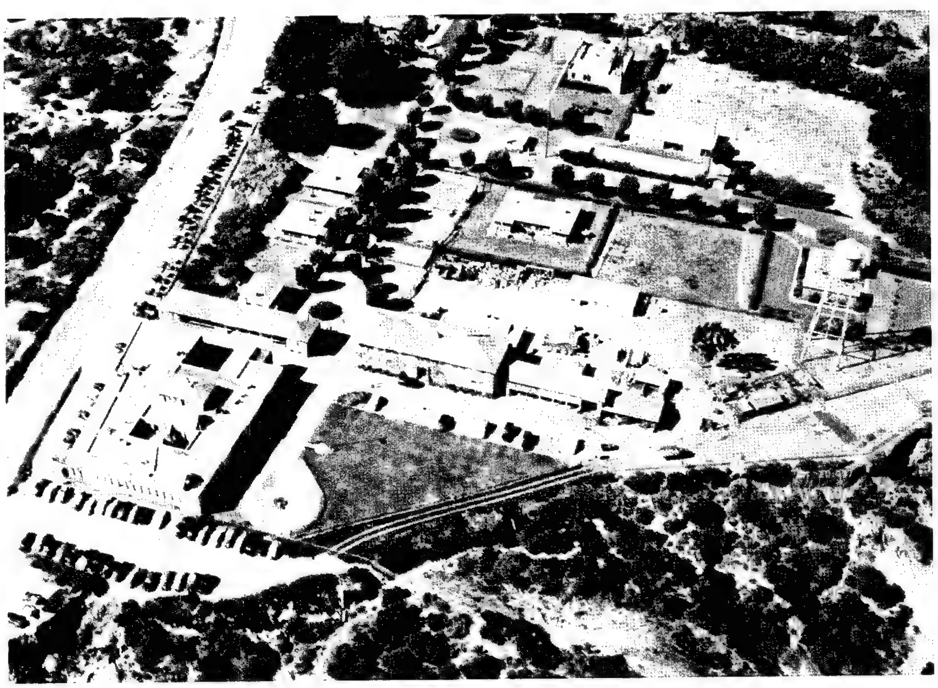
Under the terms of the OSRD contract, the Navy built all new buildings at the San Diego Laboratory. The first headquarters building (today, Building 4) began construction in 1940. Construction of the next two buildings (known as Buildings 1 and 2, Topside) began in late 1941 and finished in early 1942. Building 1 housed the cafeteria and the stockroom. Building 2 contained the machine shop in its basement and offices in the upper two floors. During wartime, the machine shop expanded into several Quonsets north of Building 2.

Neither Building 1 nor 2, however, was well suited as a laboratory, and the topside location was inconvenient to the waterfront. As a result, in 1942, the Navy began another structure on grounds provided by the Naval Training Station. The site adjoined the Fleet Sonar School, the user of much UCDWR work. This building, first occupied in August 1943, was designed as a temporary structure but, like most such buildings, proved to be enduring. Today, Building 3 is the Admiral Kidd Officers Club at the Naval Training Center. Another building, a combined galley and housing for enlisted personnel, was completed and later modified to accommodate WAVES. Today, this is the NOSC Topside Library.

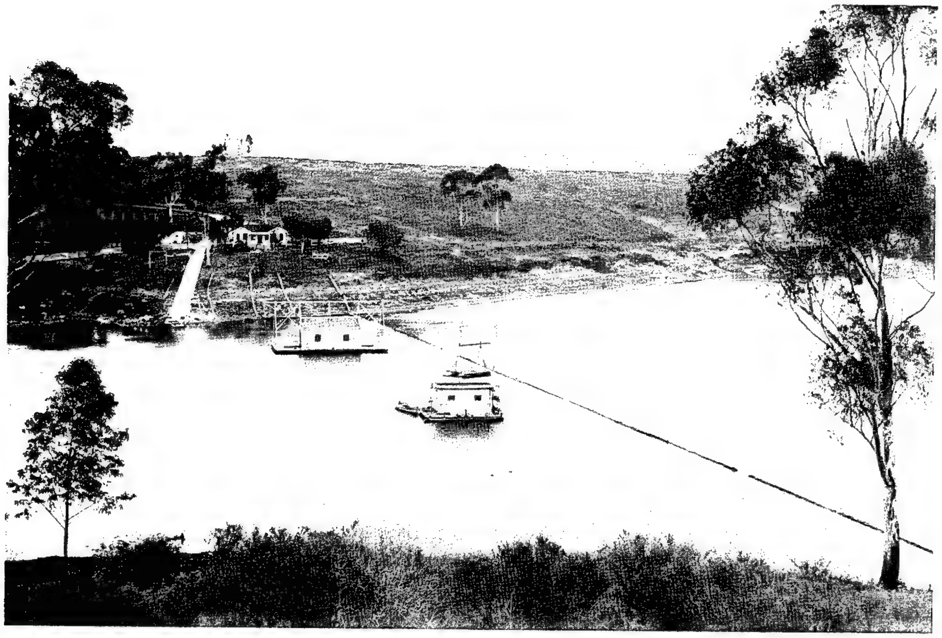
As a result of increased staff, UCDWR temporarily moved its headquarters to the Bridges Mansion off Chatsworth Boulevard near Point Loma High School. The Bridges family leased the mansion to the Navy. Known as "Building X," the mansion was first occupied in June 1944 and also housed the UCDWR support group: business, publications, and drafting, as well as parts of the oceanographic and training devices sections.



Navy Radio and Sound Laboratory, Building 4, under construction. View to northeast from Catalina Boulevard.



Navy Radio and Sound Laboratory, 1943. View to northwest with Catalina Boulevard at left. Navy Radio Station, Point Loma, in background.

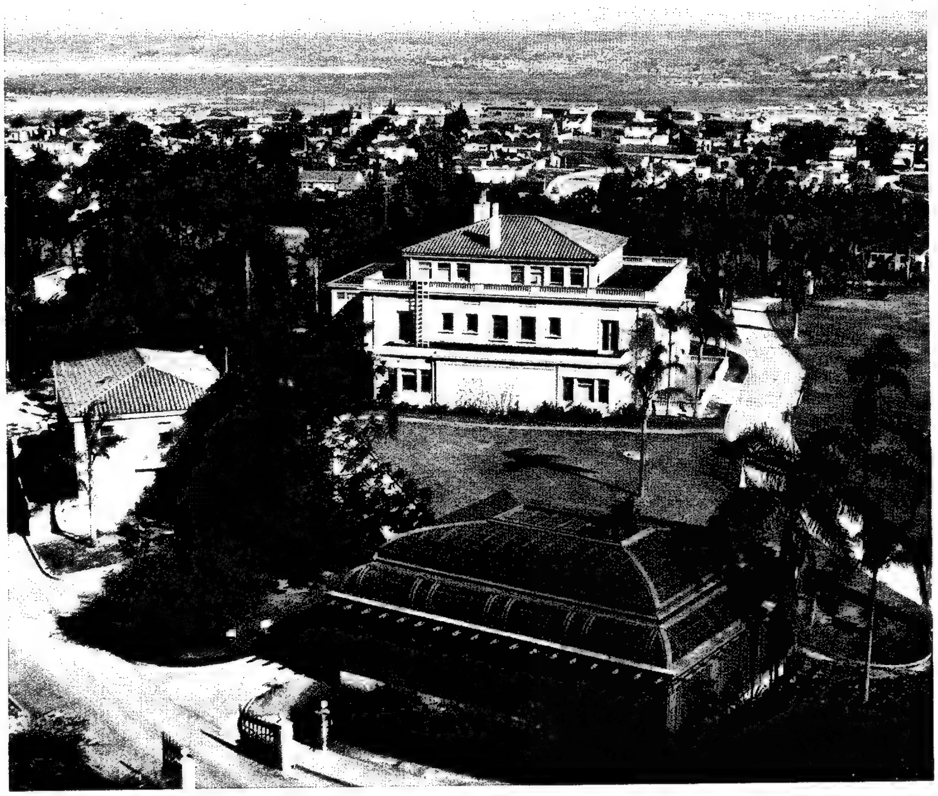


Sweetwater Lake, 17 miles from Point Loma, was used as a field station for the transducer program.

Wartime Field Stations

As the work of the San Diego Laboratory grew, so did its need for more specialized facilities. In addition to its other work, UCDWR designed transducers and acoustic homing torpedoes. Originally, the Laboratory calibrated transducers from a barge anchored in San Diego Bay, but the heavily used bay was a poor environment for taking sensitive measurements. In 1943, the Navy began using Sweetwater Lake, 17 miles southeast of Point Loma. The reservoir was deeper (60 feet in places) than San Diego Bay and free of the background noise present in the bay or in the open ocean.

From 1943 to the end of the war, one of the highest priority tasks at the Laboratory was the NAC and NAD Sound Beacons, self-propelled sonar decoy devices that would enable U.S. submarines to evade Japanese sonar. The heavy demands of the transducer program ruled out using Sweetwater Lake, so the Navy negotiated with the City of San Diego for the use of another reservoir, El Capitan Lake, 32 miles from Point Loma.



"Building X." In June 1944, UCDWR moved its headquarters to the Bridges Mansion off Chatsworth Boulevard.

San Diego: Research and Fleet Support

Radar

Even though it was a small facility, NRSL was entrusted with some of the most important experimental work done anywhere in the Navy: testing the Navy's first operational radar set. NRSL then used the set to train fighter interceptor pilots at the Naval Air Station, North Island. Beginning in October 1941, the Laboratory began to train radar operators as well. At that time, the Fleet had only a few qualified radar operators, and radar was a closely guarded military secret.

NRSL grew as its work extended to improving radar and radio transmission and reception. By 1943, NRSL research had shown that poor radio reception, previously attributed to weather or hostile jamming, was often due to self-interference. NRSL radio researchers established that the design and arrangement of antennas and their proximity to parts of a ship's superstructure, such as funnels and masts, caused self-jamming. Proper layout of antennas could solve this problem. As a result, in 1944, the Bureau of Ships (BuShips) made NRSL responsible for high-frequency (HF) antenna development, a mission that has remained to the present.

Navigation Systems

During the war, Laboratory researchers developed radar beacons, known as "racons," to assist in navigation. By the end of the fighting, radar was in sufficiently widespread use on ships of all descriptions that the Coast Guard was operating a racon station on the top of Point Loma. The racon station fulfilled the same protective function as the lighthouse had in the past. By war's end, a network of navigational beacons at both high and low frequencies extended over all continents and constituted an important aid to navigation of radar-equipped aircraft.

Sonar

Before 1943, the sonar school taught only how to operate and maintain the equipment. No one knew enough about sound in the ocean to teach anything about how to best use the sonar equipment.

The maximum effort and greatest contributions of both NRSL and UCDWR between 1941 and 1943 were in research. The physics of sound in the sea was not well understood. Sound propagation can be greatly affected by currents, marine organisms, water temperature, salinity, depth, and the structure of the ocean bottom. The San Diego Laboratory carried out studies and experiments on sound propagation, sound scattering, target strengths, ambient noise, etc. A brand-new science, entirely related to oceanography, had to be invented on a "crash basis."

This effort led to knowledge that the sonar schools and the Fleet could use to teach personnel how to use sonars to detect and attack submarines. The same knowledge was also used to teach U.S. submarines how to evade enemy sonar. During this time, information was also acquired for harbor defense, and an extensive series of charts of the Pacific was prepared by Laboratory oceanographers.

This broad knowledge base in such new categories then allowed development of equipment in 1944 to 1945 that led to important victories by the Fleet.

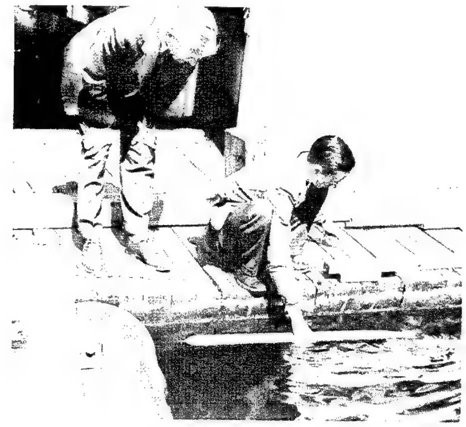
Fleet Support

Sound Decoy Devices

UCDWR scientists developed several sound decoy devices for submariners. Known as the NAC and NAD Sound Beacons, these self-propelled decoys emitted noises similar to U.S. submarines and could follow a preset course for 30 to 60 minutes. In 1945, NAD Sound Beacons were used by the Fleet to jam enemy sonars by transmitting echoes at exactly the same frequency as Japanese sonars.

QLA

UCDWR also developed an FM, high-definition sonar system, the QLA. The QLA evolved from Echoscope, an earlier project.



NAD Sound Beacon. Used to jam enemy sonars, this self-propelled decoy could follow a preset course for 30 to 60 minutes.

The Echoscope mixed a continuous signal with a continuously returning echo on the same frequency so that target range could be calculated. The Echoscope was tested successfully in early 1942 but could not be developed further for 2 years, due to a shortage of suitable transducers and the absence of basic research to develop accurate engineering design data.

Early in 1943, as the focus of submarine warfare began to shift from defense to offense and from antisubmarine warfare (ASW) in the Atlantic and Mediterranean to prosubmarine warfare in the Pacific, UCDWR engineers began to adapt the Echoscope to the role of sonar, whereby its outputs could be displayed on a cathode-ray tube (CRT) screen. In February 1943, a scanning sonar was tested in San Diego Bay. UCDWR's shops completed an

engineering prototype in the spring of 1944. The data generated by the sonar were presented visually on the CRT screen and audibly through earphones. Tests in the Mediterranean early in 1944 showed that the sonar could detect mines. This sonar, called the QLA, was the first sonar to provide a plot display of multiple targets and to offer an excellent capability as a moored-mine detector. UCDWR built a few QLA sonars, but once the design was complete most of the sonars were made in Hollywood, California, by Western Electric Company. The QLAs were constructed to serve several purposes: submerged close-contact navigation, submarine detection, under-ice navigation, and mine detection. By the summer of 1945, 48 QLA sonars were with the submarine fleet, enabling U.S. submarines to penetrate the heavily mined Japanese Inland Sea. In the final months of the war, QLA-equipped submarines had effectively severed communications between the five main islands of Japan.

Sea and Swell Forecasting

Another example of the importance of the research done by the San Diego Laboratory was "sea and swell" forecasting: an effort led by Dr. H. U. Sverdrup. During the invasion of Tarawa, 21–24 November 1943, U.S. Marines suffered a disaster when heavy surf swamped landing craft before the men got to the beaches. Although the island was eventually captured, many Marines drowned. Thanks to the sea and swell forecasting manuals produced by the San Diego Laboratory, such a tragedy never happened again throughout the many invasions of Pacific islands during the rest of the war.

Submarine Command, Pacific

During the latter part of the war, the increased activity of our own submarine forces in the Pacific caused the prosubmarine aspects of the San Diego Laboratory program to assume major importance. With over half of the Laboratory's activities directed toward one or another aspect of prosubmarine warfare, the visits to the Laboratory by Admiral C. A. Lockwood, Jr., then Commander Submarine Force Pacific Fleet, and his interest in many of the devices under development, greatly stimulated this part of the program. By the middle of 1944, UCDWR had representatives in the Pacific Area attached to the Submarine Command almost continuously. Field engineering was emphasized: fitting newly developed electronic devices to ships, debugging the devices, and teaching sailors and officers how to use them. UCDWR personnel trained sailors in maintenance and participated in numerous fleet trials.

Civilians in Uniform

As part of their research, a few scientists accompanied submariners on patrol in war zones. The scientists wore uniforms similar to those of officers' except that a small insignia at the top denoted civilian status. Even though few of the scientists at UCDWR had direct experience fighting U-boats, the scientists learned quickly and were able at times to offer tactical advice. For example, submarines had learned to avoid the pinging of active sonars by submerging more deeply as the pings got louder. To defeat this tactic, UCDWR personnel helped the Fleet develop a technique for a two-ship coordinated attack whereby one ship "pinged" while its partner attacked the unsuspecting submarine.

Pasadena: Caltech at War

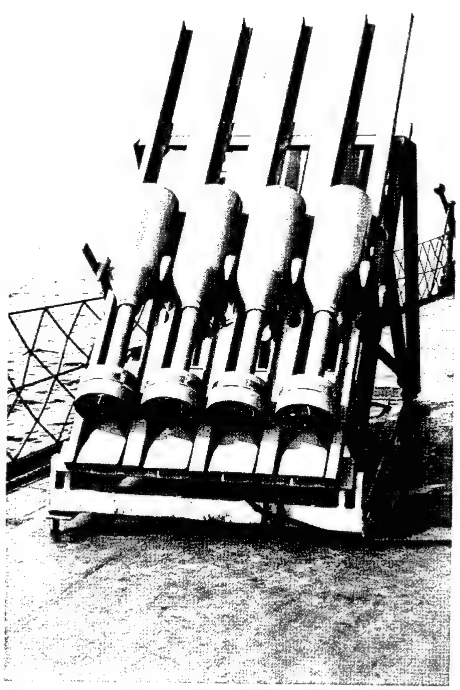
Naval research at the California Institute of Technology (Caltech), Pasadena, was another product of wartime collaboration between higher education and OSRD. In May 1940, as Germany overran France, concerned faculty at Caltech established a "Council on Defense Cooperation" that contacted NDRC to offer its services. The Council stated in its report that there were 221 members of Caltech, including 95 professors and instructors, willing to devote part or all of their time to national defense. Of these volunteers, 34 had served in military service in World War I. In 1941, NDRC signed a contract with Caltech to develop rockets, and Dr. Charles C. Lauritsen became the head of the wartime rocket development program.

Antisubmarine Rocket (ASR)/Mousetrap Launcher

The military potential of Caltech rockets could be seen with the development of an antisubmarine rocket (ASR), the launcher for which became popularly known as the "Mousetrap."

The U.S. Navy needed to learn what happened to projectiles as they hit the water and how the fuzes of fast-sinking depth charges functioned. Because the launcher for the British-developed "Hedgehog" depth charge had a powerful recoil, it was limited to large ships such as destroyers. The Navy needed a lighter version of this "ahead-thrown," standoff weapon for smaller ASW vessels.

Initially, progress was slow due to problems finding a suitable propellant. The parallel development of dry-extruded powder for the Hedgehog enabled Caltech researchers to complete the Mousetrap, a reduced version of the Hedgehog that gave smaller craft a powerful antisubmarine weapon.



By the fall of 1942, Mousetrap ASRs were in extensive use along the Atlantic Coast and in the Caribbean. Six months later they saw extended service in the Pacific and were promoted for use on ships as large as destroyer escorts. Rather than being used in place of depth charges, the ASRs were used in conjunction with them whenever the presence of a submarine was suspected. If ASR firings from Mousetraps resulted in further evidence of a submarine (such as an oil slick), then the depth charges were used. In some cases, the rockets reportedly ruptured the pressure hulls and forced the submarine to surface and become susceptible to attacks. The ASR was credited with many assists in submarine attacks and is historically the first Caltech rocket to be fired against the enemy. Since the Caltech program began the Navy's modern rocket program, the ASRs from Mousetrap launchers became the first Navy rockets of the new era to see tactical use.

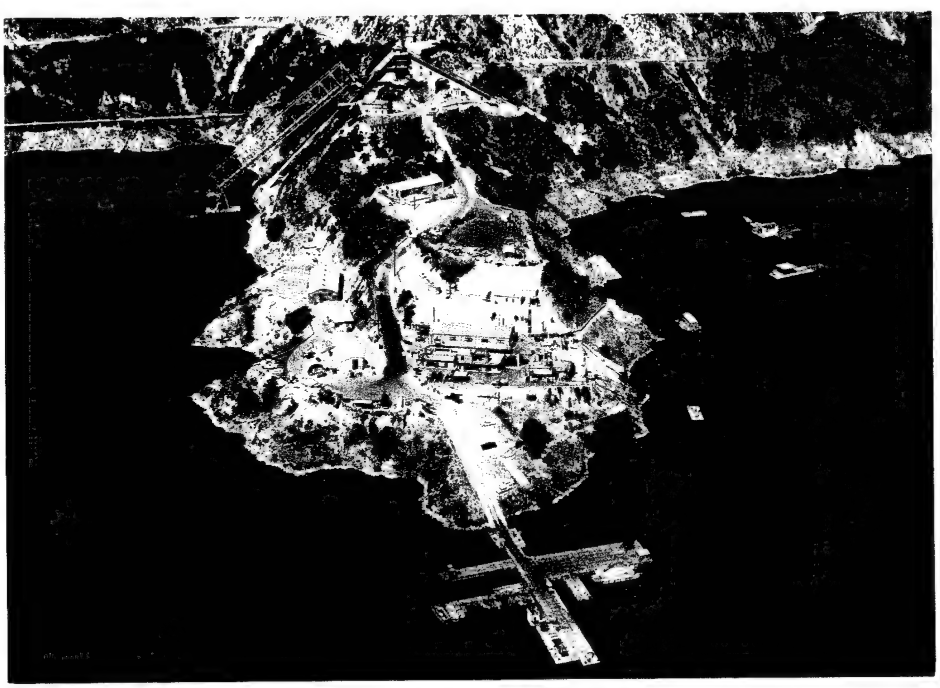
"Mousetrap" Launcher. Mousetrap-launched antisubmarine rockets were credited with many assists in submarine attacks during World War II.

Air-Dropped Torpedoes

By 1943, Caltech's work had grown to encompass underwater ordnance, specifically air-dropped torpedoes. The Navy needed scientific and engineering expertise to make torpedoes that could be dropped at the end of a brief, high-angle descent (which reduced the likelihood of the airplane being shot down) and that would still run true. Thus, the Navy needed a test facility to experiment with different angles of launch (corresponding to aircraft altitude and speed when releasing a torpedo) and to study the effects of these different angles and speeds of water entry on torpedo performance. The Torpedo Mk 13 was the only aircraft-launched torpedo available for fleet service at that time. Naval aviators laid down the basic parameters for the research: aircraft speed would be 350 knots, and the altitude of release would be 800 feet (compared with the 100 feet at the Battle of Midway that had led to such catastrophic losses of aircraft and crew). Exactly what design features required modification they did not know.

Early in 1943, Caltech scientists began to build a fixed-angle launcher to test water entry of air-dropped torpedoes. Because of the need for secrecy, a remote site in the San Gabriel Mountains was chosen: the Morris Dam reservoir, 20 miles east of Pasadena. The launcher was a 300-foot tube that could propel torpedoes into the water at a 19-degree water-entry angle. The launcher could also vary the speed of torpedoes (and thus their impact). In addition, a bridge, a crane, and various buildings and camera positions were built. By August 1943, the basic equipment was in place.

The Navy provided torpedoes, and Caltech engineers built additional dummies that matched real ordnance in weight, propulsion, and hydrodynamics. The Morris Dam tests showed that when the Mk 13 torpedo hit the water at 350 knots, its fins and rudder would be bent or the control mechanisms damaged. As one engineer recalled, "The solution to these problems consisted of several things, but the major change was the shroud-ring welded onto the tail fins, which stiffened them, strengthened them, and at the same time provided a control surface that stabilized the torpedo during the critical water-entry period. That, together with



Facilities at Morris Dam reservoir. Caltech built unique facilities at Morris Dam to test water entry of air-dropped torpedoes.

some internal improvements in the gyroscope and other control components, really made the torpedo an effective weapon again." The ring-tail had been developed by Caltech researchers for the "Mousetrap" ASW weapon. They then adapted it for an air-launched torpedo. Improved heat treating of the blades reduced damage to torpedo propellers at water entry, and the gyroscope was ruggedized.

The Morris Dam tests suggested that the Mk 13 torpedo could be safely dropped from 800 feet and at speeds of 300 knots. By the summer of 1944, the ring-tailed torpedo had been tested, and the Fleet had accepted delivery of the first 1000 torpedoes thus modified. The ring-tailed torpedo first saw operational use on 4 August 1944, and it paid off for the Fleet in the tremendous victories won by Navy aviators at the Battle of Leyte Gulf in October 1944. Sixty Japanese ships were sunk at a cost of seven U. S. vessels.

Naval Ordnance Test Station (NOTS)

The Navy's rocket program was, for all purposes, the Caltech program, and if it were to succeed it needed Navy support, particularly in providing the ranges and aircraft. The separate requirements for a rocket proving ground and an aviation ordnance station were eventually combined into one proposal. The two key architects of that proposal were Caltech's Dr. Lauritsen and Navy Commander Sherman E. Burroughs, Jr., a Bureau of Ordnance (BuOrd) officer fresh from combat where the limitations of naval aviation weapons were apparent.

Acceptance of the proposal by the Navy led to the establishment, in 1943, of the Naval Ordnance Test Station (NOTS) at Inyokern, approximately 155 miles northeast of Los Angeles. Burroughs was promoted to Captain and took command of the fledgling Station in December 1943. Personnel at the Station included only four officers and a small crew of enlisted men. Civilians consisted of a few scientists and technicians who commuted from Pasadena to Inyokern.

The Burroughs–Lauritsen contacts in these early years were particularly important for they set the pattern that would become traditional at NOTS in respect to the military-civilian team. From the Burroughs-Lauritsen association came answers to the technical problems as they related to facilities and Station operations. Lauritsen's headquarters were at the Kellogg Laboratory on the Caltech campus at Pasadena, but the contacts with NOTS were frequent.

Facilities

By early 1944, there was a general trend toward building permanent rather than temporary facilities at Inyokern. This shift was influenced by the turning tide of war.

As the United States shifted to the offensive, more people became concerned with the future peacetime Navy. Officers who had witnessed the nation's traditional peacetime disinterest in experimental ordnance facilities and who had personally observed the World War I demobilization looked for ways to make a stronger Navy and one that was abreast of technology.

On 1 February 1944, the Secretary of the Navy released $9,500,000 for construction at the Station. On 16 February 1944, another $1,553,833 was released to begin construction of a propellant manufacturing plant at China Lake, a new site 4 miles from the center of the community.

Naval Ordnance Test Station, Inyokern, CA. First base of operations at NOTS in California's Mojave Desert.

Wartime Transitions

Wartime activity at NOTS peaked during the closing months of 1944. A turning point had been reached for Station construction—ranges, administrative and test facilities, Navy housing—and also for rocket development programs.

The history of NOTS achievements during World War II includes not only the development of rocket weapons but also fleet training in the combat use of such weapons. Nevertheless, it is the hardware that is most often associated with the NOTS wartime effort: spinners,

fuzes, warheads, launchers, rocket sights, and rockets such as the Holy Moses and Tiny Tim.*

NOTS was to evolve from a wartime station serving the rocket programs of Caltech and the rocket training needs of the Fleet to a permanent center for weapon research and development. The transition plan that evolved set the pattern of the postwar years. Rocket development and test work would be transferred from Caltech to NOTS. Rocket production would be picked up under a broad contract with the General Tire and Rubber Company. The torpedo launching facilities at Morris Dam, along with the associated torpedo programs and underwater studies, would become a substation of NOTS Inyokern. Propellant work and activities would be absorbed by the new China Lake Pilot Plant. China Lake would later become one of the largest Navy research and development laboratories in the country.

Professors at War

By 1945, whatever doubts the Navy and Congress may have felt in 1939 about funding research and development had been answered. Equipment developed at Pasadena and San Diego had saved American and Allied lives and had enabled American sailors to sink German U-boats in the Atlantic and Japanese ships of all descriptions in the Pacific. San Diego's sonar research had helped to train sailors in fighting a world war on two oceans—an assignment more demanding than those offered by any university. For the Navy's scientists in San Diego and Pasadena, many of whom had come from farther afield than UCLA or Caltech, working for the Navy had enabled them to research problems full-time, to get to sea to test their hypotheses, to publish their results promptly, and to hear the heartfelt thanks of those whose lives depended on the results of their work.

*For further information on specific NOTS wartime projects, see Christman, A.B. 1971, *History of the Naval Weapons Center, China Lake, California, Vol. 1, Sailors, Scientists, and Rockets.* Naval History Division. Government Printing Office, Washington, D.C. and also Gerrard-Gough, J.D. and A.B. Christman, 1978. *History of the Naval Weapons Center, China Lake, California, Vol. 2, The Grand Experiment at Inyokern.* Naval History Division. Department of the Navy, Washington, D.C.

Fort Rosecrans Batteries

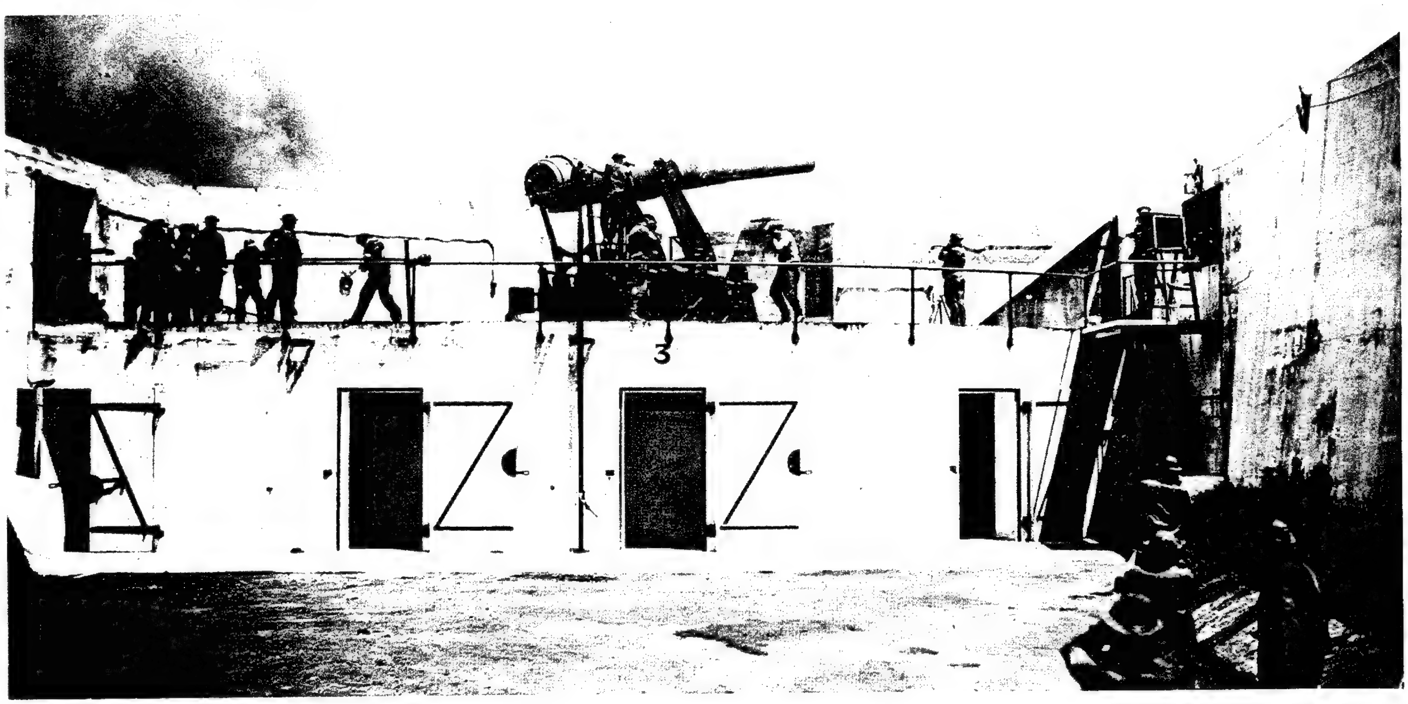
Throughout the 1920s, Fort Rosecrans was reduced to the caretaker status of keeping guns and equipment in good condition. The garrison remained small, although activity increased somewhat during the later years of the decade.

Despite the de-emphasis of armament during the 1920s, additional batteries of antiaircraft guns had been installed on Point Loma by 1930. The increased artillery consisted of two batteries installed to cover the southwest, west, and northwest approaches to San Diego Harbor. The installations were known as Battery Point Loma (located on the west side of the peninsula below the Cabrillo National Monument lighthouse) and Battery Gillespie (located on the northwest corner of the military reservation).

From 1930 to 1940, Point Loma's defenses were revitalized. On 22 July 1936, Battery White was practice-fired for the first time in 11 years. The following year construction of the new building and an additional battery started. The new battery was called Battery Strong and represented the latest in seacoast fortifications designed to defend against attack by battleships and long-range and carrier-borne aircraft.

In 1939, with the outbreak of war in Europe, and France falling in

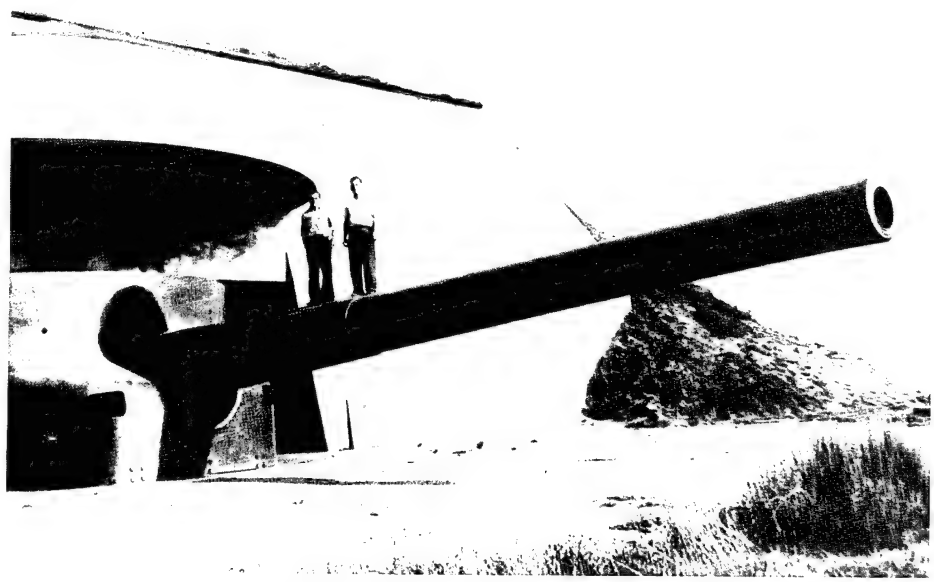
Battery Wilkeson, Fort Rosecrans, 1910. View of emplacement during target practice. The 10-inch disappearing gun shown was one of four Buffington-Crozier 1895 models installed in 1897-98.



1940, the U.S. concern for defense increased. By 1940, this concern accelerated the schedule for construction of coastal defenses. San Diego's plan called for a network of artillery batteries and fire-control facilities along approximately 30 miles of coastline.

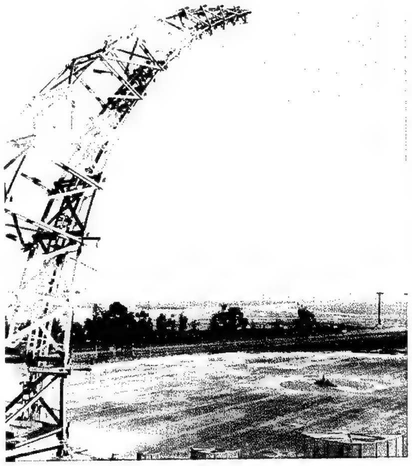
The plan called for batteries in three locations: Point Loma, Silver Strand, and Fort Emory. Battery Strong, begun in 1937, was completed. Construction of the other batteries began in early 1941, before the attack on Pearl Harbor, and continued through 1945. Following is a list of Point Loma's batteries and their present status.

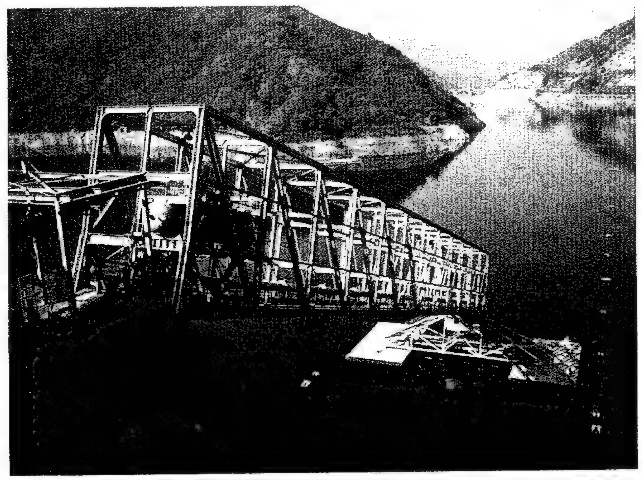
- *Battery Wilkeson was completed in 1897. (In 1915, the battery was split in half and the northeast half of the battery was renamed Battery Calef.) Today the battery is in good condition and is used by the Submarine Base for workshops and storage.*
- *Battery White, completed in 1916, was declared obsolete and scrapped in 1942. Today, NOSC uses Battery White for storage.*
- *Battery Whistler, completed in 1920, was declared obsolete and scrapped in 1942. However, Battery Whistler is being used today as part of the Arctic Submarine Laboratory.*
- *Battery Gillespie was completed in 1930. This battery provided cover for the west and northwest approaches to San Diego Harbor until completion of Battery Woodward. Today, Battery Gillespie is intact although in a state of disrepair.*



Battery Ashburn, Fort Rosecrans. One of two 16-inch guns installed and proof-fired in 1944.

- *Battery Strong was completed in 1941 and is presently used by NOSC for surveillance technology.*
- *Battery Zeilin, completed in 1942, was only a temporary emplacement of Navy guns; it no longer exists.*
- *Battery Humphrey was completed in 1942. NOSC currently uses this battery for satellite communications.*
- *Battery Woodward was completed in 1943. With the completion of Battery Woodward, Batteries Zeilen and Gillespie were discontinued. Battery Woodward is currently in use as a radio facility.*
- *Battery Ashburn was completed in 1944. This structure has been extensively altered by NOSC and has no resemblance to the original building. NOSC currently uses northern Battery Ashburn for microelectronics and southern Battery Ashburn for theater communications.*





Introduction

National leaders praised wartime research and development efforts and agreed that peacetime R&D was vital to the nation. After the war, organization of research changed. The Navy bureaus took over management as well as sponsorship of the laboratories. In San Diego, NRSL and UCDWR became the Navy Electronics Laboratory (NEL). In Pasadena, the facilities previously operated as part of Caltech's wartime rocket and torpedo development work were transferred to become the NOTS Pasadena Annex.

NEL continued NRSL's work in ship antenna development and directivity. Efforts were directed toward minimizing the number of antennas and using ship structural elements to enhance antenna performance. NEL continued UCDWR work on radar beacons; the precision RACON system went to the Fleet in 1949. Work continued on aircraft recognition systems, which included development of the Mk X Identification Friend or Foe (IFF) prototype. NEL also completed the Sound Fixing and Ranging (SOFAR) system for locating survivors at sea. And NEL's long interest in the interaction of submarines with the submerged environment led to pioneering studies of the Arctic.

NOTS Pasadena Annex continued work on air-dropped torpedoes, a task made more challenging with the advent of jet airplanes. Engineers built innovative new facilities to test new designs. Work also continued on standoff ASW weapons and led to the development of the rocket-propelled Weapon A.

Peacetime Defense Research

Although the U.S. military scaled down severely after the war, the government had learned the value of scientific research and development and wanted to maintain a permanent, peacetime research capability that could expand rapidly if needed and keep abreast of technological change. Vannevar Bush spoke for many, inside and outside of military science, in his final report as head of OSRD:

> *In this war it has become clear beyond all doubt that scientific research is absolutely essential to national security. The bitter and dangerous battle against the U-boat was a battle of scientific techniques—and our margin of success was dangerously small. The new eyes which radar supplied to our fighting forces quickly evoked the development of scientific countermeasures which could often blind them. This again represents the ever continuing battle of techniques. The V-1 [unguided missile] attack on London was finally defeated by three devices developed during this war and used superbly in the field. V-2 [the first guided missile] was finally countered only by capture of the launching sites.... There must be more—and more adequate—military research during peacetime. We cannot rely on our Allies to hold off the enemy while we struggle to catch up. Further, it is clear that only the Government can undertake military research; for it must be carried on in secret, much of it has no commercial value, and it is expensive. The obligation of Government to support research on military problems is inescapable. It is essential that the civilian scientists continue in peacetime some portion of those contributions to national security which they have made so effectively during the war.*

It remained for the Navy to organize its postwar research effort.

The Bureau Structure of Navy Research

The Navy emphatically supported the need for peacetime R&D, even as it demobilized its big wartime fleet. Although OSRD had managed the new wartime laboratories at San Diego and Pasadena, their actual funding had come mainly from three of the Navy's material bureaus (Ships, Ordnance, and Aeronautics), which traditionally supplied the material needs of the Fleet. As the war ended, the Navy decided to replace OSRD by having the bureau sponsors of its R&D become the managers of its R&D, too.

In 1946, Navy organization distinguished between the command responsibilities of the Chief of Naval Operations (CNO) and the support role played by the material bureaus. CNO determined fleet needs, and the bureaus filled those needs. The seven bureaus, some dating from the 1840s, were all organized around particular functions central to the fleet's activities: medicine (BuMed), ship construction (BuShips), yards and docks (BuDocks), supplies and accounts (BuSandA), personnel (BuPers), ordnance (BuOrd), and aeronautics (BuAir). BuShips, BuOrd, and BuAir sponsored most of the research and development at the two laboratories that became NOSC.

San Diego: From NRSL/UCDWR to Navy Electronics Laboratory (NEL)

In 1945, the U.S. Navy Electronics Laboratory (NEL) was established to continue the electronics and underwater acoustics work performed by its two World War II predecessors, NRSL and UCDWR. (NRSL was renamed the U.S. Navy Electronics Laboratory on 29 November 1945, and on 30 June 1946, UCDWR's remaining projects and contracts were absorbed and continued by NEL.) Many UCDWR employees transferred to the civil service payroll of NEL. A certain portion of work also came to NEL from incomplete OSRD work being done for the Navy at Harvard and the Massachusetts Institute of Technology (MIT).

Placed under BuShips, NEL was tasked "to effectuate the solution of any problem in the field of electronics, in connection with the design, procurement, testing, installation and maintenance of electronic equipment for the U.S. Navy." Captain Paul Hord managed the transition to NEL. He was designated Commanding Officer (CO) and Director and had overall command responsibility for the laboratory, much as a CO does for a ship at sea. In Captain Hord's view, the function of the Navy Electronics Laboratory would shift from fleet support to basic research. As he put it in 1946, "To fulfill its mission, the Laboratory must remain a scientific institution wherein scientific work is performed by scientists under the direction of scientists. The future of NEL depends solely on the scientific results it produces. The stature of NEL is directly proportional to the stature of its scientific personnel."

In January 1946, the position of a civilian "Superintending Scientist" was created but remained unfilled until the autumn of 1948 when J. P. Maxfield was appointed.

Defining Postwar Research

BuShips broadly defined what was expected of NEL's postwar naval research: (1) to study and improve all the electronic equipment aboard a single ship or single class of ships; (2) to continue to develop, test, modify, and support radar and radio communication equipment developed at San Diego or at other Navy laboratories; (3) to study, at the level of fundamental research, the propagation of electromagnetic energy in the atmosphere and of sound in the ocean; (4) to continue to develop sonars and training aids for sonar operators; and (5) to assist the Fleet by training its personnel as needed. These mission areas, seemingly narrowly drawn, would require basic research in several related fields, notably physics, mathematics, meteorology, and marine biology and would also require the development of professional expertise in electrical, electronic, and mechanical engineering.

BuShips, as its name implied, designed, built, and maintained the ships of the Fleet, including their electronics. BuShips organized its work in electronics on the basis of projects, which were given to research and development teams at its laboratories. This direct tasking promoted very close ties between project managers at NEL and their "sponsors" in the Bureau—officers who administered BuShips funds allocated for the particular task.

NEL Growth

Although the Navy as a whole scaled down after the war, the San Diego Laboratory grew. In terms of physical plant, NEL originally comprised three buildings on Point Loma (the present Topside buildings 1, 2, 4, and various small buildings), two waterfront buildings, an abandoned coastal defense battery at the tip of the Point (Battery Humphrey), and field stations at two city reservoirs (Sweetwater and El Capitan) plus another at Sentinel, Arizona, adjacent to Luke Air Force Base.

In August 1947, NEL gained 11 acres from the Navy's Fuel Facility as well as all structures of the Small Craft Facility (today NOSC Bayside). In the summer of 1947, NEL also took possession of USS *Baya* (SS 318) to support

underwater research. In 1949, NEL acquired 11.2 more acres of Bureau of Public Health lands and buildings (the old Quarantine Station at Ballast Point).

The growth of work at NEL was such that the 80th Congress authorized construction of a large new building. The Commandant of the 11th Naval District, Rear Admiral Wilder Baker, broke ground for the new structure on 24 June 1949. The building was designed to be built and opened in stages, so that the first wings could be used while the rest was still being built. Wings 1 and 2 were built over the next 3 years, and the structure (known as Building 33) opened in 1950.

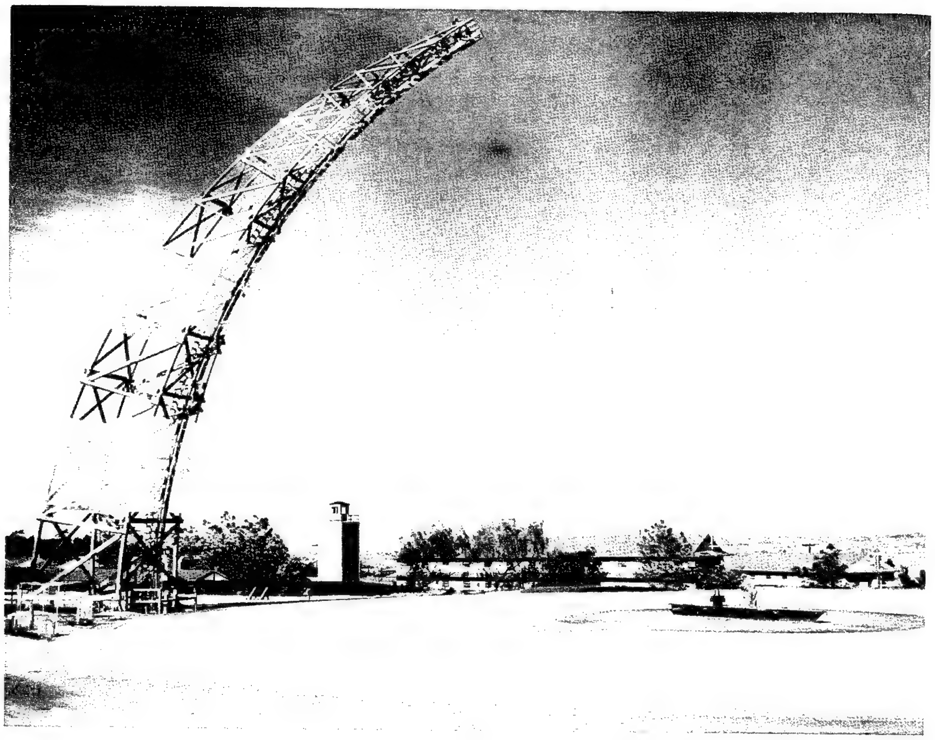
Groundbreaking ceremony for Building 33 on 24 June 1949. Wielding the shovel is RADM W. D. Baker, USN, Commandant of the Eleventh Naval District. Watching (center) is CAPT R. Bennett, USN, Director of NEL.

NEL: Continuing Research in Peacetime

Electronic Architecture

NEL continued the wartime studies of ship antenna development and directivity undertaken by NRSL. Self-interference was a problem that advances in electronics only increased. New radars in some destroyer classes required an additional mast to accommodate the forest of radar and counter-radar antennas. During the postwar years, considerable effort went into minimizing the number of antennas by multicoupling, that is, using one antenna to receive signals on different wavelengths simultaneously. A parallel effort involved using ship structural elements to enhance antenna performance.

In 1945, NEL began building the Antenna Model Range to support this work. By 1947, NEL engineers



Antenna Model Range. The model ship, 1/48th scale, is mounted on a brass-covered turntable 22 feet in diameter centered in a lead-covered circular concrete base.

began the first tests with scaled-down brass models of ships. The Model Range uses scaled-up frequencies on scaled-down ship models (1/48th scale today) to measure antenna performance and to assess the interaction (desirable and undesirable) among the radiating elements and the ship's superstructure. An important milestone of this effort was the recommissioning of USS *Mount McKinley* (AGC 7) in 1951, in which NEL engineers reduced the number of antennas to one-third the total originally required, with no loss in performance.

The UC Connection Preserved: The Marine Physical Laboratory

When UCDWR and NRSL activities were combined to form NEL, a group of San Diego scientists continued their UC affiliation and remained at Point Loma to form the Marine Physical Laboratory (MPL). MPL was established in 1946 at NEL to continue basic (i.e., pure scientific) research on underwater acoustics started by UCDWR. MPL's director was Professor Carl Eckart, past assistant director of UCDWR's Sonar Data Division. MPL, with Navy sponsorship, conducted research in oceanography and physics and remains (in 1990) an important Navy contract laboratory managed by the University of California's Scripps Institution of Oceanography.

Navigation Systems

During the war, UCDWR had developed radar beacons (racons) to assist in navigation. During the late 1940s, NEL electronics engineers developed the first of a series of navigation systems based on advances in electronics. The result, the precision RACON system, went to the Fleet in 1949. The RACON system allowed precise navigation of harbors and beachheads and was used for tactical air support during the Korean War.

Identification Friend or Foe (IFF)

UCDWR had worked on aircraft recognition systems (generally known as IFF) during the war. The principle behind IFF was that a suitably equipped aircraft or ship could electronically interrogate an unknown aircraft and determine whether it was hostile or friendly. An airplane equipped with an IFF system automatically transmits a series of pulses in the form of a code to the receiver on the ground, in the air, or onboard ship. Originally developed to avoid shooting down one's own aircraft, IFF could be and was extended to encompass submarines and surface ships.

However, in 1945, IFF systems could only respond to an interrogation. They could not convey detailed information as to type, unit, or course. Beginning in 1947, NEL researchers developed the selective identification features that enabled interrogating IFF systems to receive detailed information from a transponder aboard a ship, submarine, or aircraft.

NEL prepared the initial concept as well as the prototype hardware of the Mk X IFF system. Operational evaluation, with 10 aircraft, took place in 1951, and the first system was with the Fleet the following year. During the 1950s, the Mk X IFF became operational with all U.S. and North Atlantic Treaty Organization (NATO) forces and continued in use into the 1970s on military and civilian aircraft and ships. As a result of NEL's pioneering work, selective identification features were incorporated into the IFF systems developed since for use by American and Allied military and civilian aircraft. The benefits of this work were primarily realized in civil air traffic control. Not only did selective identification features enable controllers to process significantly more information, but data from the new system proved easy to format for entry into computer systems.

The SOFAR System

During the war, UCDWR had begun work on the Sound Fixing and Ranging (SOFAR) system for locating and rescuing ship and aircraft survivors at sea. As implemented, the SOFAR system required survivors from a plane to drop a miniature depth charge into the water. The depth charge would sink and explode at the optimal depth for sound transmission, 3500 feet. Hydrophones placed at the same depth and cabled to shore stations

SOFAR system. Model study for SOFAR movie.

would receive the signal and by triangulation locate the source of the sound and hence be able to direct rescuers. After the war, NEL scientists completed the system, which consisted of a network of three radio direction-finding stations in the eastern Pacific, to provide long-range reception of low-frequency signals deep in the ocean. Later, the SOFAR system was used for basic research in underwater sound.

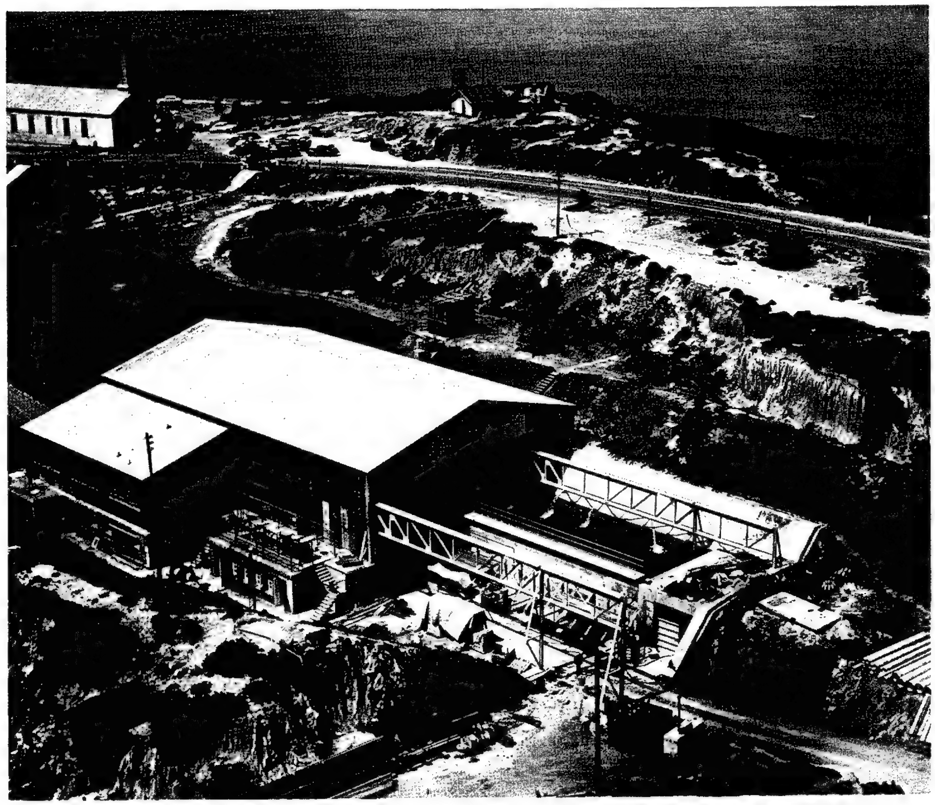
Pioneering Arctic Research

The Navy's submarine arctic work was an outgrowth of NRSL's antisubmarine warfare (ASW) and harbor defense work of World War II. The Canadian Navy had asked that Puget Sound be evaluated since its harbor defense system was the most complete and elaborate of all World War II systems. The evaluation was expanded to study why German U-boats had been so successful in sinking ships in the Gulf of Saint Lawrence and evading Canadian ASW efforts. Ocean conditions were thought to be similar in Puget Sound and the Gulf of Saint Lawrence. Since the U-boats had used the winter ice cover in the Gulf to evade ASW ships, the question of submarines under ice also became a part of the joint U.S./Canadian study.

This study led to Dr. Waldo Lyon's early experiments with diesel-electric submarines. Up to this point, the ice canopy appeared to present an insurmountable barrier both to surface ships and air-breathing diesel-electric submarines. Everyone knew the physical hazards of collisions with ice, and submarines were more frail and had far less buoyancy than surface ships. So how could they navigate beneath the ice and hope to survive? At that time, almost no knowledge of the underside of the ice canopy existed. Many thought it was perfectly smooth, so that a ski-equipped submarine could transit the Arctic by gliding along the underside of the arctic ice pack.

The skills necessary to handle submarines in the open ocean differed greatly from the skills that would be necessary to dive, surface, and clear obstacles under the ice. The variations in salinity due to ice melting would affect buoyancy and other aspects of handling submarines. Oceanographers knew that the Bering and Chukchi Seas were quite shallow (140 feet in places) and feared that the rest of the Arctic Ocean would be equally hazardous. Plus, submarines had no way of knowing reliably how close they were to either the ocean bottom or the ice cap, so no matter how skillful a submariner, the chances of collision, damage, and sinking were real. Finally, diesel-electric submarines had to recharge their batteries by periodically running their diesel engines, either while surfaced or while "snorkeling" (proceeding just below the surface with an air pipe extended like a periscope to ventilate exhaust and take in air for the crew and the diesel engines). The Navy's *Naval Arctic Operations Handbook*, published in 1949, was dismissive: "The development of the transarctic submarine remains in the realm of fantasy."

Dr. Lyon and a small group of physicists at NEL disagreed. Dr. Lyon hypothesized that practical navigation beneath the ice required a scanning device, that is, active sonar, similar to the QLA developed at UCDWR. In the summer of 1947, Lyon was aboard USS *Boarfish* (SS 327) when it penetrated 6 miles under the polar ice cap. The scanning sonar worked fine, and the crew had no difficulties using it. In a pioneering, but little noticed, technical report of 1948 (NEL TR 88), Lyon argued that, "The reality of a polar submarine that can navigate the entire Arctic Ocean is not only admissible, but may be an immediate practicality." As Lyon put it, "The prerequisite equipments for under-ice navigation are standard, available equipments, though the techniques of interpretation are new." Dr. Lyon and like-minded NEL scientists soon demonstrated just how immediately arctic navigation could begin. They set to work in the late 1940s on converting a fathometer for under-ice navigation by inverting it on the topside of a submarine so that it could provide accurate information on the ice-fields through which the submarine was sailing. By devising a method of printing echoes from the fathometer on a strip of paper, Dr. Lyon's work enabled a submariner to follow his boat's progress underneath the ice.



Battery Whistler after conversion for use by NEL. The old mortar battery was converted to a laboratory for testing the effects of seawater and different water pressures on materials devices used by submarines.

The first inverted fathometer was mounted on the upper deck of USS *Carp* (SS 338) in September 1948 and tested in the Arctic Ocean later in the year. Thus equipped, *Carp* made vertical dives and ascents through open-water lakes in the ice pack. These accomplishments proved Dr. Lyon's point—that properly equipped and handled submarines could safely navigate even in the shallows of the Bering and Chukchi Seas.

Tested over a series of arctic cruises, the inverted fathometer revealed what many had suspected—the arctic ice pack was diverse in character, varied in thickness, and had enough leads (narrow channels of water) and polynyas (areas of open water) to allow submarines to surface. But there were also dangerous "ice keels," deep ridges that hung down from the main canopy, which a submarine had to avoid.

Once the basic equipment and techniques had been developed, experiments to develop information about sound propagation in the Arctic were necessary to learn exactly how the equipment functioned. NEL's work in developing the technology for piloting submarines under the ice was a combination of developing the sonar equipment, charting the sea floors, and learning about the ocean under the ice and sea-ice physics. In addition, NEL scientists, like their World War II precursors, accompanied the submarines to instruct submariners in using NEL-developed equipment, to evaluate performance, and to pinpoint problems that showed up in the field. To support these summer expeditions year-round, NEL began in the late 1940s to convert an unused U.S. Army coastal defense mortar battery, Battery Whistler, into the Deep Submergence Laboratory. This laboratory would be used for testing the effects of seawater and different water pressures on materials and devices intended for use by submarines. Known subsequently as the Submarine Research Facility, it became the Arctic Submarine Laboratory in 1969.

Pasadena: From Caltech to NOTS Pasadena Annex

Caltech had already decided in April 1945 not to continue direct involvement with Navy weaponry. As a result, BuOrd in October 1945 took over direct control of rocket and torpedo development, and about 80 percent of Caltech contract employees working in those groups accepted civil service employment with the Navy.

General Tire and Rubber (GTR) operated the main Pasadena building, the Foothill Plant, as a Navy contractor. Under the contract, BuOrd dealt directly with GTR, whose employees administered the test station at Inyokern as well as the scientific activity in Pasadena and at Morris Dam. In July 1948, approximately 400 employees of GTR accepted civil service positions with NOTS in Pasadena, bringing the total number of employees there to 700. For several years, Pasadena housed the administration of NOTS: personnel, payroll, and facilities, in addition to the underwater ordnance department, and was generally referred to as the "Pasadena Annex" or later as "NOTS Pasadena," which is the name we will use here.

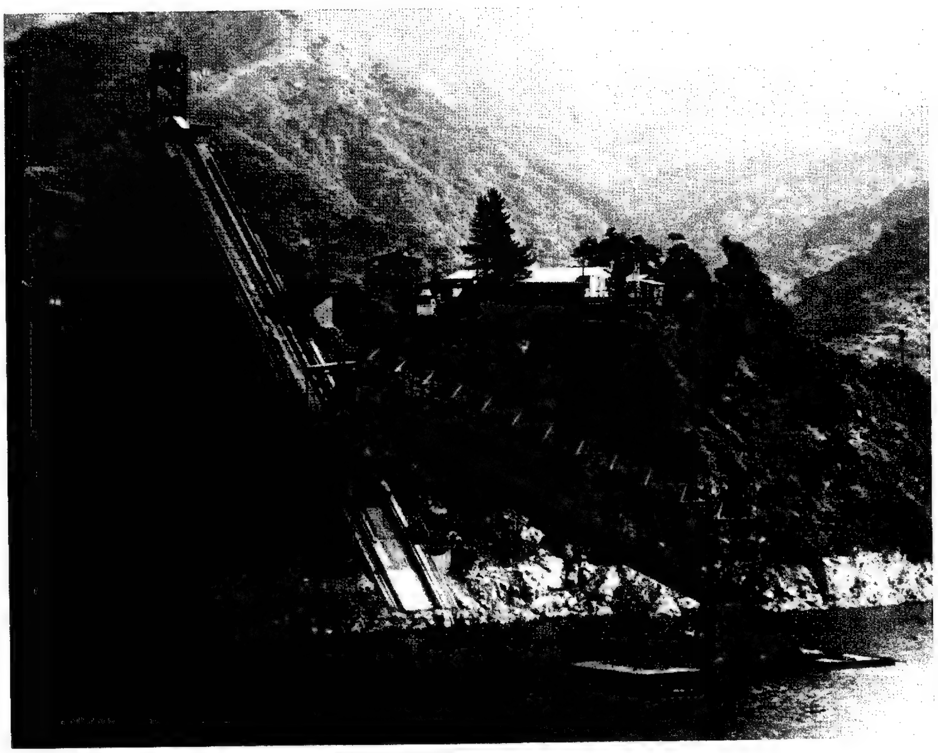
NOTS Pasadena: Lightweight Torpedoes in the Jet Age

Air-Dropped Torpedoes

The advent of jets gave a new impetus to research on air-dropped torpedoes, since the increased speed of the new aircraft in turn increased the stresses of the torpedoes' water entry. Also, with improved antiaircraft armament and superior, radar-directed fire control developed during the war, aircraft had to drop their torpedoes farther away from their targets. Thus, air-dropped torpedoes would have to be faster and have greater range than those already in use. In July 1946, BuOrd formally tasked NOTS Pasadena to develop a 1000-pound, high-speed torpedo that could be dropped from an aircraft traveling at 600 knots (~700 mph) and at an altitude of 10,000 feet. To put this in perspective, remember that only 5 years earlier, the British "Swordfish" aircraft that torpedoed the *Bismarck* were biplanes flying at 100 mph and dropping their ordnance at 50 feet above the sea.

Whether a faster torpedo with greater range could be built was not yet clear in 1946, but it was plain to NOTS that the existing test facilities at Morris Dam would not be adequate. As early as 1943, engineers at Morris Dam had started work on improving the Mk 13 torpedo, the first torpedo designed specifically for aircraft launching. Initial results indicated that only a torpedo of a radically new design would permit a higher water-entry speed caused by faster jet aircraft.

VAL at Morris Dam. An enhanced version of the fixed-angle launcher, the VAL allowed scientists to vary the angle of water entry of torpedoes to approximate different air-drop speeds and altitudes.



The Variable-Angle Launcher (VAL)

Plans for an enhanced version of the fixed-angle launcher at Morris Dam had been drawn up before the war ended, but construction of the new variable-angle launcher (VAL) did not begin until 1947. General Tire and Rubber, through a construction contract, completed the VAL by the summer of 1948. As designed, the VAL was a 300-foot steel bridge with a launching tube 22.5 inches in diameter. By pivoting one end of the bridge on

a crosspiece that connected two floating barges, the angle of water entry could be shifted to approximate different air-drop speeds and altitudes. Compressed air shot a torpedo out of the 300-foot launching tube, and a battery of high-speed cameras filmed the projectile as it hit the water. Instrumented testheads aboard the torpedoes measured the stresses of the impact. All the resulting data were available for subsequent analysis.

Important ancillary facilities at Morris Dam built during this time included a rocket launcher for studies of trajectory and velocity of projectiles underwater and a barge-mounted rail launcher to model over-the-side torpedo launches or to study the impact of exploders against armor plating. Similarly, General Tire and Rubber built small barge-mounted VALs for smaller ordnance and for higher initial velocities than possible with the main unit. The propulsion laboratory at Morris Dam was expanded for experiments with chemical fuels, high-energy batteries, and various thrust-producing mechanisms.

Hydrodynamic Simulator

Prior to the late 1940s, the only means to test torpedoes was by actually running them at sea. This practice was not only expensive and infrequent, but often if a run failed, the reasons for the failure could not be determined. In 1944, Pasadena engineers began to develop test equipment to simulate the underwater environment of a torpedo. The result, the Hydrodynamic Simulator, was finished in June 1948. The Hydrodynamic Simulator was a large tank in which an actual torpedo (or other missile) could be subjected to the same forces and motions it would experience in live conditions. The idea for the simulator was based on using a 5-inch gun mount. The gun was replaced with a separate carriage, and the simulator was designed so that a Mk 13 torpedo could be placed in the carriage so as to have three degrees of freedom; it could roll about the longitudinal axis, pitch nose up and down, and change course heading. The efficiency of the torpedo's control system could be assessed and qualitative performance criteria established quickly and with much less proof-firing of new torpedoes. Thus, by the late 1940s, the Navy had a unique facility and unmatched technical expertise on which to call.

Over the years, the Hydrodynamic Simulator has gone through many upgrades to extend and expand its capabilities in lock-step with the development of successive generations of U.S. torpedoes. Capabilities such as target acoustics simulation and environmental modeling were added, and simulator target models were upgraded to reflect new intelligence data. The simulator has made major contributions to both the submarine- and air-launched torpedo programs and is doing so to this day. Now called the Hybrid Simulator, it is one of the only on-line facilities in the free world that can do realtime hardware-in-the-loop simulation to support the development, test, and evaluation of all U.S. torpedoes as well as the torpedoes of many Allied nations.

Weapon A

The increased range of submarine-launched torpedoes and the increased detection ranges offered by sonars developed during the war produced a need for standoff ASW weapons that could be launched farther ahead than previously fired by destroyers or other ASW craft. During the war, the Hedgehog and the Mousetrap had provided good service, but the function of a research and development laboratory is to anticipate, not merely react to, developments in other technologies. So, in 1946, NOTS Pasadena began work to develop a rocket-propelled standoff ASW weapon.

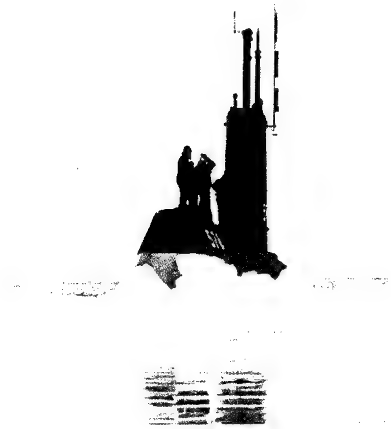
Working with the Naval Ordnance Laboratory in White Oak, Maryland, NOTS Pasadena developed Weapon A within 3.5 years. Fired from a deck loader, Weapon A carried a 250-pound warhead. Its solid-fuel-propelled rocket could carry it 2400 feet from the ship firing it. Weapon A entered the Fleet in 1951 and remained in inventory until 1969.

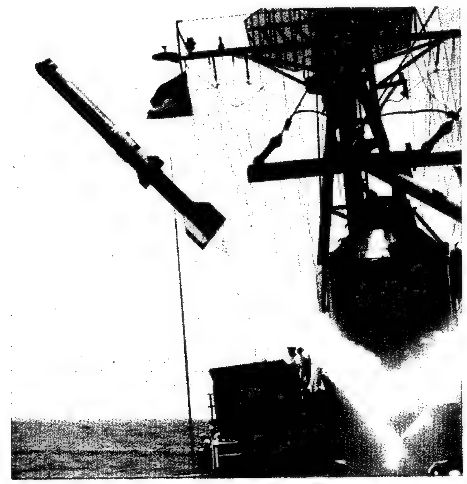
Sidewinder

During the postwar years, NOTS Inyokern became home to Dr. William McLean, a man who would later play an important role as Technical Director of laboratories at China Lake and San Diego. Once a student of Dr. Lauritsen's at Caltech, Dr. McLean transferred to Inyokern in 1945.

From 1945 to 1948, Dr. McLean developed the fundamental concept that was to transform guided missile technology: Free the missile from total dependence on both guidance control and the releasing aircraft by placing the control unit within the missile itself and designing it to seek out the radiation emitted from the target. As the target maneuvered, the missile would "lock on" to follow the radiation to its source.

Dr. McLean's design philosophy was unique for the times: If a part didn't work, find a way not to use that part at all. By solving each problem as it arose and by adding his own brand of engineering ingenuity, Dr. McLean designed the new air-to-air missile for tail attacks and named it for the sidewinder rattlesnake—an ancient resident of the Mojave Desert. The first Sidewinder missiles were released to the Fleet in 1956 and became unsurpassed in accuracy and reliability. Sidewinders are still being used by the U.S. Navy, U.S. Air Force, NATO countries, and other Allies. For his efforts on Sidewinder, Dr. McLean received the President's Award for Distinguished Federal Civilian Service, presented by President Eisenhower in 1958.





Introduction

Defense R&D basicallly had three partners: industry, universities, and DoD laboratories, each with a clearly defined role. Increasingly, industry played a larger role in military R&D because as the pace of technological change accelerated and the workload increased, the laboratories had to contract for more of their R&D products.

While "redefined," the role of the Navy laboratories in the 1950s changed little. The structure and management of the laboratories also remained much the same.

The bureaus continued to manage and sponsor NEL and NOTS throughout the 1950s. Direct management of each laboratory was shared by a military and a civilian manager, an arrangement still used today.

New technology changed the course of R&D at NEL and NOTS. The advent of nuclear-powered submarines required new methods for detecting and fighting submarines. Nuclear-powered submarines also made further arctic submarine operations possible; equipped with under-ice navigation equipment developed at NEL, U.S. submarines made significant under-ice passages. With the technical feasibility of a true multithreat warfare environment came a need for better methods of assessing incoming information; as an answer to that need, NEL played a major role in developing the Navy Tactical Data System (NTDS). Also, progressively longer ranged aircraft and broader surveillance fields required more sophisticated war games; to meet that challenge, NEL developed the Navy Electronic Warfare Simulator (NEWS).

The success of Weapon A in the postwar era paved the way for NOTS Pasadena to develop a rocket-assisted torpedo in the 1950s; in 1956, NOTS Pasadena began work on the Antisubmarine Rocket (ASROC), a rocket-propelled weapon capable of launching either a nuclear depth charge or a lightweight acoustic homing torpedo. When the Navy began work on the Polaris missile in 1956, NOTS Pasadena, with its unequaled experience in underwater ballistics, was called upon to develop the technology. Later, in 1958, NOTS Pasadena began development of the Mk 46 torpedo, which went on to become the principal lightweight torpedo for the United States and approximately 30 Allies.

Laboratory Management and Direction

The end of the Korean War in 1953 did not produce a decline in defense spending, which remained high at "Cold War" levels. Still, the new Eisenhower administration wanted to shrink government, including the military. Although a career soldier, President Eisenhower harbored serious reservations about the increased role of the military in peacetime America. He acted to halt the growth of government, including the military. On his retirement in 1961 he warned against the "military-industrial" complex. This concern naturally affected NEL and NOTS.

In 1955, President Eisenhower appointed the Commission on the Organization of the Executive Branch under former president Herbert Hoover. (The Commission was commonly known as the "Second Hoover Commission.") Its task force on research and development evaluated the military laboratories and endorsed the administration's attitude that the military should use universities for basic research and should involve industry as an integral part of design and development. The Second Hoover Commission evaluated both NEL and NOTS, praising them for the excellence of their facilities, technical staff, and leadership. They were "among the best of the military centers for research and development operations." The strength of these Navy laboratories, observed the Commission, was their ability to work within the military framework and to manage tightly focused programs on behalf of the services. Neither university laboratories nor private industry were as well equipped. Thus, in the view of the Second Hoover Commission, defense research had three partners: industry, universities, and DoD laboratories. Each had roles that it could perform best, and from this partnership would emerge an integrated and economical program of defense research and development.

Bureau Laboratories

Throughout the 1950s, NEL and NOTS were bureau laboratories, run directly by Navy material bureaus (BuShips and BuOrd, respectively). From 1946 until 1966, this pattern of sponsorship continued, with NOTS oriented toward BuOrd tasks: weaponry, guided missiles, underwater fire control systems, torpedoes, and the like. BuOrd was responsible for the design, purchase, issue, and maintenance of all guns, bombs, torpedoes, and rockets that the Navy used. Its R&D division assigned R&D tasks to various field activities; university laboratories, such as the Applied Physics Laboratory of Johns Hopkins University; contractors; and its own in-house laboratories, notably the Naval Ordnance Laboratory (NOL) then at the Washington Navy Yard and NOTS at Inyokern and Pasadena. The R&D division of BuOrd had eight separate product branches, two of which developed especially close relations with NOTS Pasadena: underwater ordnance and fire control.

Whereas BuOrd concerned itself with the Navy's armaments, BuShips involved itself with the design and construction of ships and their equipment. BuShips determined NEL's R&D agenda through funding specific projects in the application of electronics and

in the application of related sciences to naval problems in the fields of acoustic and electromagnetic detection and location, communications, navigation, classification, identification, countermeasures, and signal and data processing.

Additionally, first NOTS and then NEL began to receive a grant for "foundational [i.e., basic science] research," which later became known as independent research. In 1959, the Navy formally established another funding category, exploratory development. Exploratory development money was allocated for the sort of practical problem-solving that the laboratories did best.

Growth and Specialization

Even though overall R&D expenditures increased, personnel ceilings and relatively low civil service pay scales made it difficult for the Navy laboratories to do everything on their own. As the pace of technological change accelerated, the laboratories had to contract for more of their R&D work, not simply for the production of the finished article whose prototype had been fabricated in-house. For example, NOTS Pasadena developed the Mk 46 torpedo beginning in 1958 with a contract with Aerojet General Corporation, also of Pasadena. Similarly, Pasadena's Antisubmarine Rocket (ASROC) was developed with Minneapolis-Honeywell as prime contractor and NOTS Pasadena as technical direction agent. Under these arrangements, overall control remained with the R&D Division of BuOrd (the sponsor), but NOTS was responsible to the bureau for the performance of the new torpedo and its compatibility with related weapons systems. The trend increasingly was for the Navy to have the system prime contractor manage subcontracts, rather than have the laboratory manage a plethora of performers. The same pattern simultaneously developed in San Diego at NEL for projects such as the Navy Tactical Data System (NTDS).

The long-term result of these relationships and pressures was for the laboratories to develop a "cradle-to-grave" engineering responsibility with contractors whereby the laboratories designed, supervised the manufacture of, and then maintained a system throughout its lifespan. In practice, system development consisted of first "selling" a sponsor on a particular project (and on the laboratory's fitness to supervise its development), successfully following through on the R&D, overseeing the fabrication of prototypes, evaluating their performance, and then supervising training and field service maintenance, including periodic updates of the operational system. During the 1950s, NEL and NOTS Pasadena successfully directed the work of contractors and in-house research to produce a number of remarkable systems.

San Diego Management

NEL's Superintending Scientist, J. P. Maxfield, retired on 31 December 1954. His successor, Dr. Franz N.D. Kurie, received the title "Technical Director" (TD), which has since become standard throughout Navy laboratories. The TD acted as senior staff adviser to the CO. However, the most detailed supervision of the work underway at the laboratory came from BuShips project officers and civilian program managers in Washington.

San Diego Facilities

Despite the inclination of the Eisenhower administration to restrain defense spending, money and responsibilities continued to flow into the laboratories throughout the decade. NEL facilities expanded steadily throughout the 1950s. In 1951, the laboratory acquired the barracks area of Fort Rosecrans from the Army (until then the largest landowner on the Point). At the same time, NEL took over Batteries Woodward, Whistler, and Strong and began to convert them into usable structures.

In 1959, NEL was given local command and plant responsibilities for everything on the Fort Rosecrans Reservation. Thus, NEL became the landlord for an additional 577 acres and 134 structures.

Oceanographic Research Tower

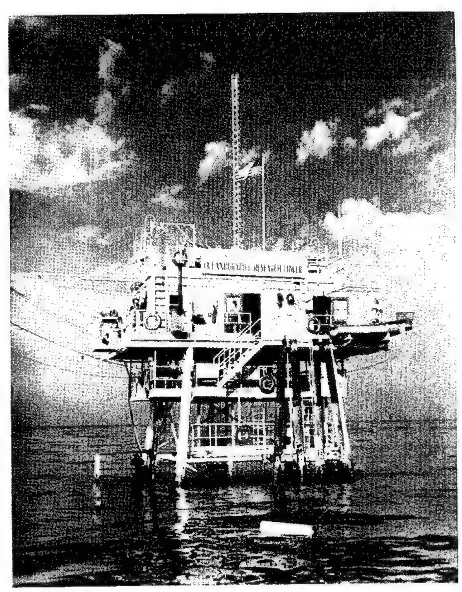
Neither a ship nor a shore installation by itself can provide the necessary conditions for the study of the ocean's shallow water and associated coastal marine environmental problems. Such research requires access to the open sea, stability, a fixed location, and a constant power supply. In 1959, NEL built an oceanographic research tower off Mission Beach to meet these requirements. Installed in 60 feet of water approximately 1 mile off Mission Beach, San Diego, the tower was easily accessible by regular NEL boat service, yet far enough from shore to provide a natural, open sea environment.

The tower's stability, based on slanting steel legs extending 63 feet into the ocean floor, assured continuous oceanographic and meteorological measurements from a fixed location. Versatile and adaptable, the tower could be used for equipment evaluation and for studies of the atmosphere, the shallow water environment, and the sea floor. Several investigations, related or isolated, could be conducted simultaneously.

Specially designed equipment supported research performed at the tower. The tower had track railings on three sides that could be used to raise and lower instrumentation to the ocean floor. NEL developed a 1-atmosphere, acrylic elevator to

Acrylic elevator at the Oceanographic Research Tower. The acrylic sphere accommodated an operator and one passenger for the descent through the 60-foot water column to the ocean floor. Ron Reich (left) and Dr. William McLean (right).

Oceanographic Research Tower.

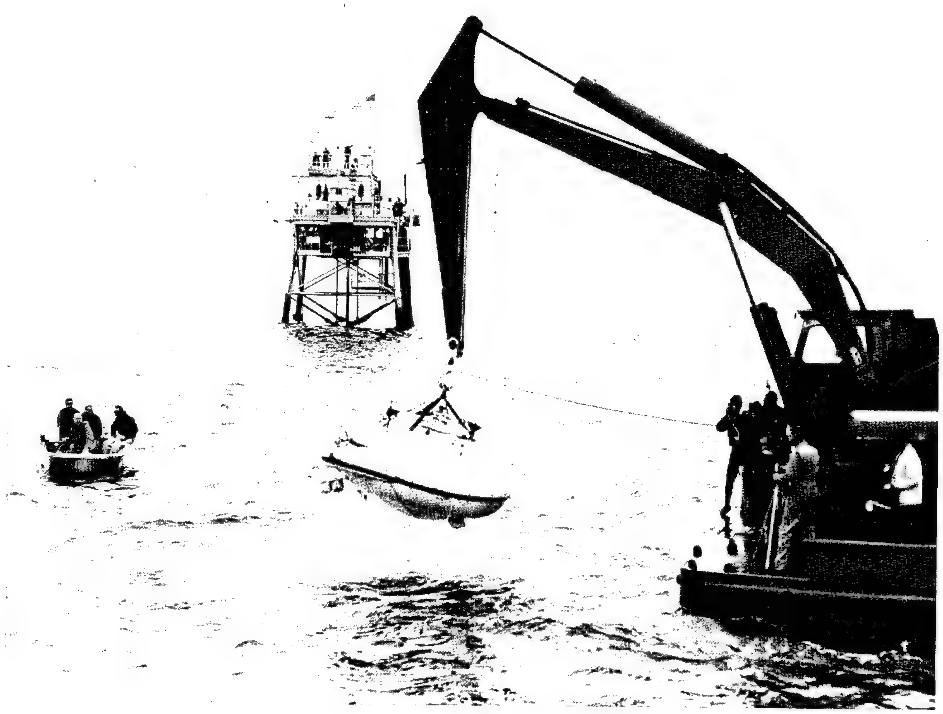


provide an observation chamber for biological and water-motion studies. The elevator "cage" was a transparent acrylic sphere accommodating an operator and one passenger for the descent through the 60-foot water column to the ocean floor. In the waters surrounding the tower, there were approximately 150 temperature sensors, waveheight sensors, and transducers hardwired to onboard instruments. Five arrays of thermistor beads continuously monitored the water thermal structure. Other equipment recorded dew point, wave motion, current speed and direction, sound velocity, and water clarity. A daily weather report, used by local authorities, originated at the tower.

Shallow-water oceanography studies predominated at the tower. Water movement throughout the entire water column was the most intensively studied variable at the tower, as it affected surface and subsurface navigation, acoustic transmission, and the permanence of equipment placed on the ocean floor. Acoustic studies centered on the propagation of subsurface sound signals, especially on the biological and physical factors that interfere with propagation, transmission, and reception. Other projects were related to electromagnetic wave propagation, marine chemistry, marine biology, marine geology, and materials research. A new research technique developed at NEL consisted of simultaneous investigations from the Cousteau diving saucer and from the tower. Joint studies included current speed and direction, water transparency, and temperature, as well as detailed studies of the sea floor.

Over the years, the laboratory's work at the tower abated, and the tower's usefulness diminished. In 1986, the tower was transferred to the Chief of Naval Research for management by the Scripps Institution of Oceanography. In January 1988, a storm razed the weatherworn and weakened structure. No plans exist to have it rebuilt.

Cousteau's Diving Saucer was used in coordination with the Oceanographic Research Tower.



NEL Tenant Activities

Personnel Research Unit

The year 1951 saw the establishment on Point Loma of the U.S. Navy Personnel Research Unit (today the Navy Personnel Research and Development Center—NPRDC). Originally, its mission was to support fleet training, education, and human resources planning, but over the years its work turned more toward psychology and human relations. In 1973, it became NPRDC, chartered to be the "principal Navy activity for conducting human resources RDT&E in the areas of manpower, personnel, education and training...and to stimulate human factors efforts in the design, development, and evaluation of new systems for operational use."

Visibility Laboratory

In 1952, the Navy moved its Visibility Laboratory from MIT to Point Loma, placing it under the Scripps Institution of Oceanography. The "Viz Lab" specialized in fundamental research on the transmission of visible light through the atmosphere and water. Its applied research focused on image formation and recognition, including camouflage. The "Viz Lab" today is a division of the Marine Physical Laboratory under the management of Scripps.

Health Research

In 1959, another Navy laboratory came to Point Loma—the Navy Medical Neuropsychiatric Research Unit, which was housed in the barracks area. Renamed in 1974, this laboratory is now called the Naval Health Research Center.

NEL: Expanding Research and Development

Navy Tactical Data System (NTDS)

NEL pioneered in automated command control by developing systems for every level of command from a single ship to the highest fleet command. NEL developed an operating model of a Coordinated Display System (CDS) that demonstrated the basic elements of an automated tactical data system for shipboard use. Previously, "tactical data systems" aboard Navy warships consisted of grease pencils, intercoms, and sound-powered phones. Shipboard weapons officers had to develop tracks manually by plotting contacts, trying to discern a pattern, and then determining which weapons system could best deal with the developing threat. The limitations of these methods had become apparent at the Battle of Okinawa in 1945 when the Japanese mixed conventional bombing runs with kamikazes—the latter offering a foretaste of missile warfare. By the mid-1950s, a true multithreat warfare environment became technically feasible where guided missiles, surface ships, submarines, and aircraft were all threats.

In April 1955, the Chief of Naval Research established a committee (the Lamplight Committee) on technical data-processing systems. In August of that year, the committee recommended a system based on a digital computer that would include a cathode-ray tube situation display, radio data links, and peripheral equipment. The system recommended would also be able to handle a full range of data-processing requirements for not only antiair warfare but for surface warfare, amphibious operations, electronic warfare, and ASW.

The Navy accepted these recommendations, and in 1956 the formal operational requirement for a Navy tactical data system was issued. As lead bureau, BuShips created a special projects office to oversee development of the initial system, called the Navy Tactical Data System (NTDS). Because the Navy's first choice, Bell Laboratories, did not think it could handle the entire project on its own, BuShips awarded prime contracts to three separate contractors in the spring of 1956: Sperry Rand's UNIVAC division (computers and system design engineering), Collins Radio (data communications links), and Hughes Aircraft (displays). NEL was tasked to do engineering and technical support for the entire program—assembling, testing, and evaluating every developmental model of all the equipment produced under the contracts. NEL also assisted each contractor with solving the technical problems that inevitably arose in the course of the NTDS project.

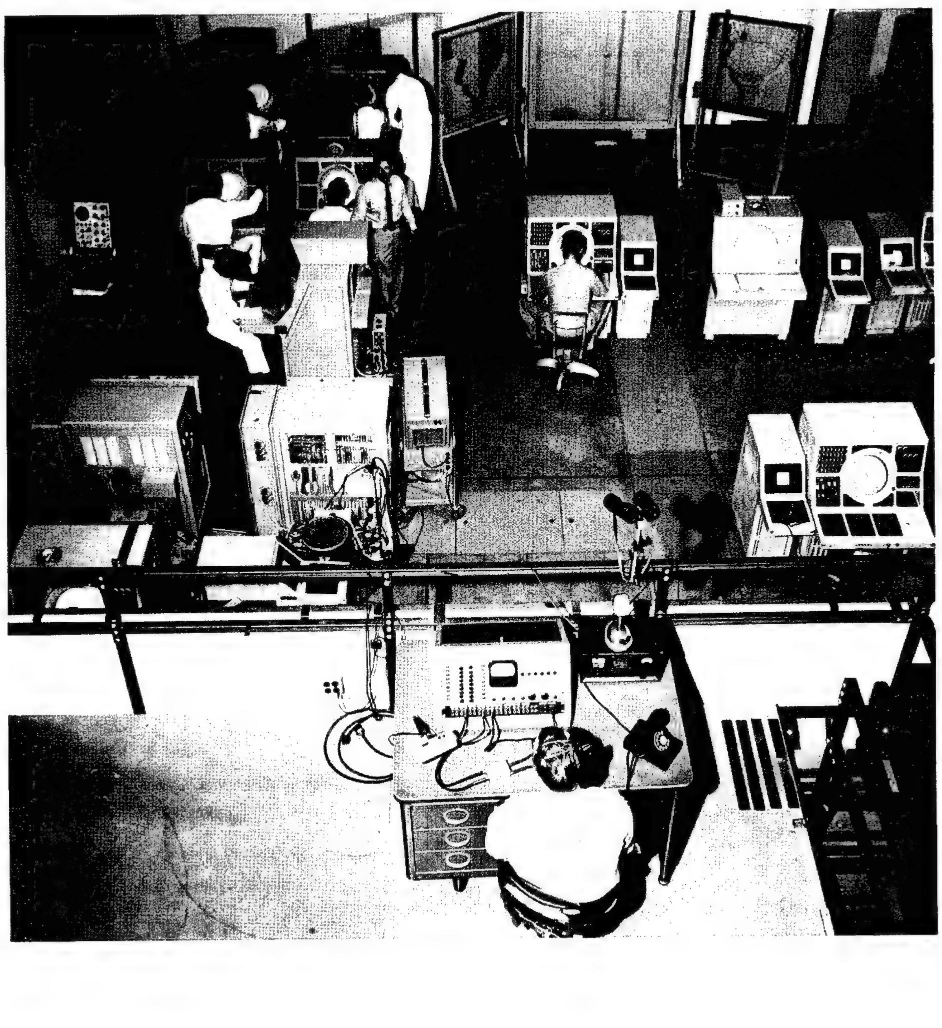
NTDS development required work that was new and not wholly accepted in the late 1950s: computer programming of realtime systems, development of computer algorithms, display technology, data transmission, and user/machine interface. NEL coordinated the entire effort, and the NTDS project at its peak employed 50 people: civil service engineers, Navy officers, and contractors on-site.

NTDS consisted of high-speed (for the time) computers, stored programs, specialized displays, and digital data links. The equipment was delivered to NEL in December 1958 for assembling and checkout. The first tests of the total NTDS system began in April 1959. NEL engineers wrote the technical evaluation procedures for the entire system and performed the technical evaluation (TECHEVAL). As lead laboratory, NEL also developed and tested both the advanced development model and the engineering development model along with the communications that made NTDS data available to other ships and aircraft.

NTDS enabled officers and seamen in a ship's Combat Information Center to establish and update tracks, determine their bearing and speed, and distribute information selectively to the relevant command or control displays. In time, with upgraded equipment and different programs, NTDS was adapted to provide automated data processing for ASW and surface warships. NTDS also offered ease of maintenance and in-service reliability. CNO approved it for service use in April 1963. Since then NTDS has had many incremental improvements, most of them engineered by NEL or NOSC.

NTDS proved to be a computing milestone. It validated the use of digital data processing and facilitated the Navy and the civilian world's shift from analog to digital data processing. The building-block concept employed in the NTDS design made it possible to configure the system for special applications and adapt it to changing requirements. Finally, NTDS exemplified the changed role of the laboratories. During World War II, UCDWR had developed hardware in-house. Only after its shops had fabricated a prototype was a contract put out to bid so a production version could be manufactured. In the face of high-technology warfare, the laboratories found themselves systems engineers for large projects involving major contractors and many subcontractors. In the 1960s and beyond, projects such as NTDS became the norm for NEL and its successor organizations—coooperative efforts between defense contractors and in-house laboratories.

NTDS training in full-scale mock-up of a shipboard Combat Information Center.



The Navy Electronic Warfare Simulator (NEWS)

The Naval War College at Newport, Rhode Island, has played regular war games since 1894. Games allowed officers a laboratory environment in which to act as commanders of ships, as commanders of squadrons or a fleet, and eventually as theater commanders. During the next 60 years, games became progressively more elaborate. Games were played first on tabletops, later on floors, with umpires monitoring the action and instructors critiquing the decision-making of players. Screens were used to replicate diminished visibility.

The advent of progressively longer ranged aircraft and broader surveillance fields led the College to consider an electronic board as early as 1945. In 1954, the War College asked NEL to develop an electronic war game. NEL began the project that year, and the result, the Navy Electronic Warfare Simulator (NEWS), was first used at the War College in May 1958. Developed before the microcomputer era, NEWS occupied three floors of the center wing of Sims Hall, the principal administration building at Newport. Commanders and staffs, up to 200 people, were housed in individual windowless rooms, each of which resembled the combat direction center of a ship or a flagship.

In a NEWS game, players were located in their own isolated command centers and provided with appropriate intelligence and typical communications from friendly forces. On a separate master-plot screen in the umpire area, the entire game was projected for the umpires, including not only position of units but also their combat effectiveness. A damage computer monitored the actions of all players and results of all combat, automatically reducing the weapons effectiveness and speed of damaged forces, and communicating own-force results to the player involved.

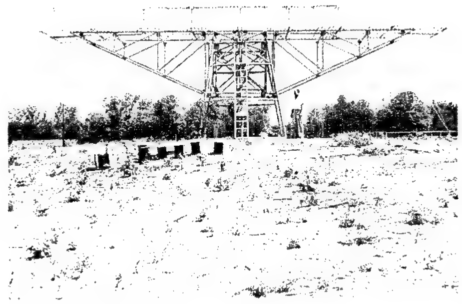
The umpires' summary plot of NEWS was a screen 15 feet in diameter on which images of simulated action were electronically portrayed. The umpires alone knew everything about the progress of a game: the position of all forces, the extent of damage to units, and the effectiveness of remaining forces. The players, however, as in real combat, got only bits of information. They might become aware that their own ship had been hit, had lost speed, was on fire, or could no longer maneuver, but they did not know for certain the location of their opponents or how much damage had been inflicted.

Navigation

NEL developed a low-frequency (LF) radio navigation system from 1950 to 1957. Known as Radux, the system (first tested in 1954) demonstrated for the first time the extreme phase stability of LF signals. Radux-equipped ships or aircraft, triangulating on three LF signals emanating from known shore positions, could determine their position to within 2 nautical miles—a remarkably accurate position compared with celestial navigation. The three synchronized Radux sites were in Hawaii, San Diego, and Bainbridge Island, Washington. Together, they covered the Northern Pacific.

Satellite Tracking

NEL established the first West Coast satellite tracking station in 1957, planned in cooperation with the Naval Research Laboratory (NRL) for the International Geophysical Year during 1957 and 1958. As it turned out, the Minitrack Station at Brown Field, California, was completed in October 1957 just ahead of the Russian Sputnik. The station, because of its location, was the first non-Soviet satellite tracking station to confirm that the Sputnik had orbited the earth. Built for Project Vanguard (the Navy's entry in the satellite program), the Brown Field station tracked Sputniks I and II and Vanguard satellites in the late 1950s. Linked by teletype to NRL, the Brown Field station fed tracking data directly to the computers in Washington.



Minitrack Station, Brown Field, CA. The Brown Field Station tracked Sputniks I and II and Vanguard satellites in the late 1950s.

Continuing Arctic Research

During the 1950s, the "fantasy" of arctic submarine operations became a reality. At the end of the decade, USS *Skate* (SSN 578) surfaced at the North Pole, dramatic evidence of the Navy's ability to go anywhere. The key technological breakthrough that made this possible was the development of the nuclear-powered submarine, which unlike air-breathing diesel-electric submarines, could remain submerged throughout lengthy transpolar cruises. It is doubtful, however, whether the Navy would have risked its new nuclear submarines had not the techniques for under-ice navigation been developed over a period of years under the direction of NEL.

In 1952, USS *Redfish* (SS 395), guided by Dr. Lyon, went 20 miles into the ice pack and remained submerged for a record 9 hours, giving a tremendous boost to advocates of arctic submarine activities.

But not until the late 1950s did a submarine capable of remaining beneath the ice canopy exist: the nuclear-powered USS *Nautilus* (SSN 571). In the summer of 1957,

Nautilus was tasked to sail beneath the polar ice prior to a NATO exercise in September 1957. As usual, Dr. Lyon was onboard the submarine when it left New London on 19 August 1957. Its mission was to penetrate to 50 or 60 miles and then return. The submarine did better, actually getting within 180 miles of the North Pole before returning. *Nautilus* covered nearly 1000 miles and remained submerged for 74 hours.

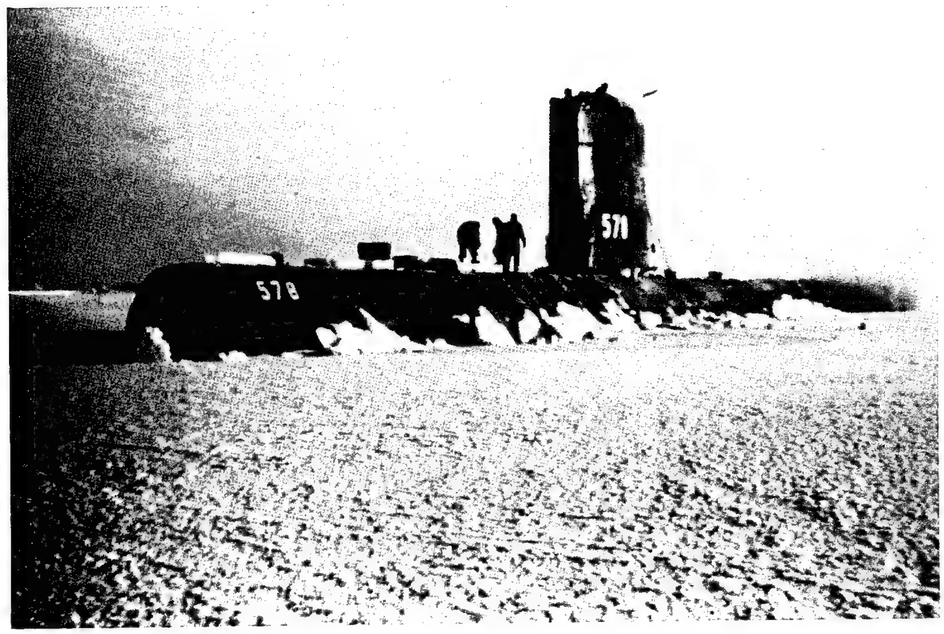
The success of *Nautilus* in making the first underwater passage into the Arctic Ocean led the Navy to plan a much more ambitious exercise for the summer of 1958—a submerged voyage from the Pacific to the Atlantic. After a winter of planning, *Nautilus* passed under the North Pole on 3 August 1958. To a nation still smarting from Sputnik, this success by a nuclear-powered submarine came as welcome news.

Dr. Lyon (left) and CDR W. R. Anderson (right) watching sonar aboard USS Nautilus *(SSN 571).*

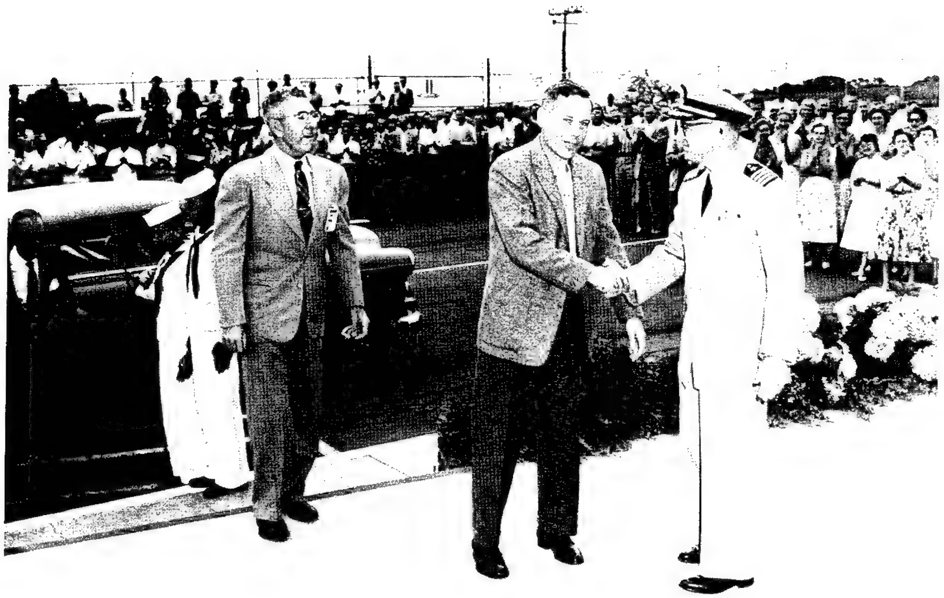
The crew of *Nautilus* left the submarine as national heroes. They received a ticker-tape parade down Fifth Avenue in New York. Dr. Lyon accompanied them, and then returned to San Diego with two trunks full of data, information for analysis at NEL. Dr. Lyon's instruments had collected more data about the Arctic in an hour than had been gathered in years of exploration from the surface.

After these two *Nautilus* voyages, two conclusions became apparent: first, the ice pack was much thicker than previously thought (as much as 65 feet, not 10 to 15 feet), and second, ice keels projected down as far as 100 or 125 feet. While transiting under the ice canopy, *Nautilus'* fathometers also mapped the Arctic Ocean floor, revealing underwater mountain ranges that rose thousands of feet.

Dr. Lyon's most famous under-ice cruise occurred in March 1959, when he directed USS *Skate* during its first breaching of the ice at the Pole. Before the cruise, Dr. Lyon, along with other NEL scientists, developed the active sonar that permitted *Skate* to penetrate the ice pack and to surface through several feet of ice. In 96 hours submerged, the submarine covered 1830 miles and eventually surfaced near Greenland to within a few miles of where her inertial navigation system had placed her.



USS Skate *(SSN 578) surfaced at the North Pole, March 1959.*



Welcome home for Dr. Lyon after Nautilus *cruise. He is greeted by NEL Commander, CAPT John M. Phelps. NEL's Archie Walker is at left, and Technical Director, Dr. Franz N. D. Kurie, is at far left.*

Deep Submergence: *Trieste*

In addition to its arctic research, NEL took part in ocean studies in other parts of the world. Swiss oceanographer Auguste Picard believed that direct personal observation by scientists was necessary to develop adequate knowledge of the ocean floor and the water column. But when he began exploring the ocean floor in the 1930s, the only available technology was the tethered bathysphere or the diving bell, unsafe due to mechanical limitations. Dr. Picard obtained support from Swiss, Italian, and French Navy sources and built two tethered bathyscaphs in the 1940s and 1950s. Having had experience in free-flight in hot-air balloons, Dr. Picard, in 1953, designed and built a free-swimming undersea vehicle with a large float (like the balloon) supporting a manned pressure sphere (like the gondola) and called it *Trieste*. Built in Italy, *Trieste* was capable of deep (20,000 feet or deeper) submergence operations.

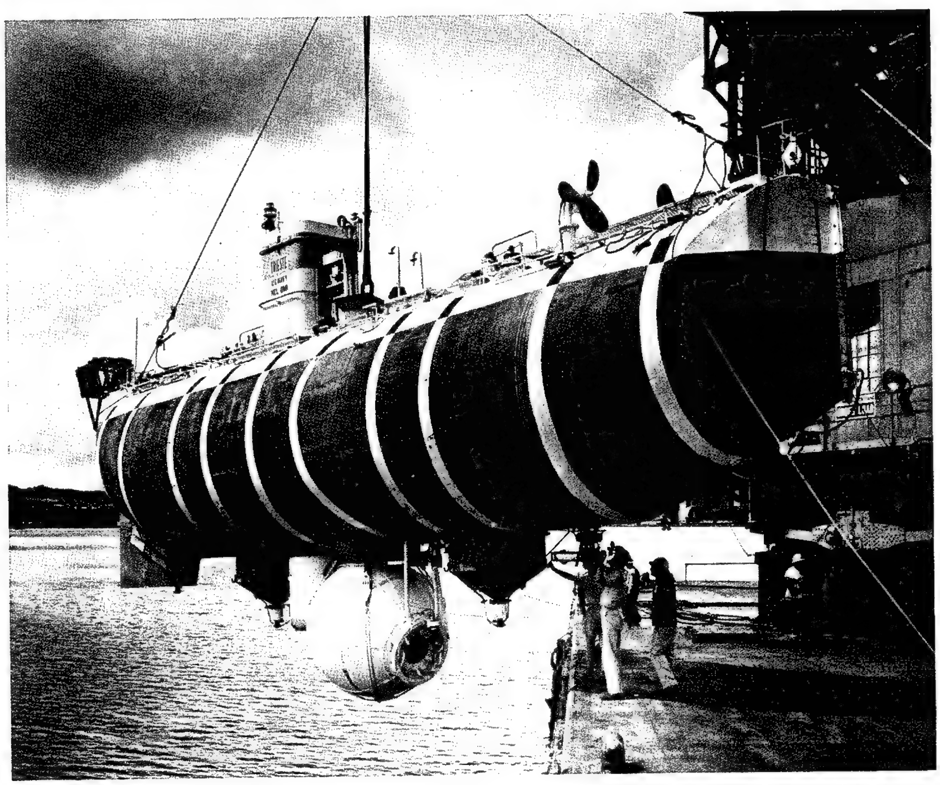
The Office of Naval Research (ONR) supported a series of Mediterranean dives of *Trieste*. ONR liked what it saw and bought *Trieste*, contracting with Picard to instruct U.S. Navy personnel in its operation. ONR gave *Trieste* to NEL to use with the laboratory's sonar and oceanographic research, since

San Diego enjoyed good year-round weather, nearby deep ocean, and ample support from fleet facilities. *Trieste* arrived at NEL in September 1958 and made its first U.S. Navy dive off San Diego on 20 December 1958.

Trieste was not simply a more capable submarine. Ordinary submarines of its era might dive to 200 or 300 feet; *Trieste* went to a world-record depth of 35,800 feet and withstood pressures of 16,000 psi. *Trieste* was 5 tons negatively buoyant, and its reserve buoyancy was provided by gasoline. The crew was limited to just two or three people, and the dive itself was limited to about 8 hours due to the capacity of the storage batteries and oxygen. *Trieste* was "fail-safe" in that any system failure triggered the release of 16 tons of ballast, which would cause her to rise to the surface.

Under NEL, *Trieste* made 78 dives between 1958 and 1963. NEL scientists used it for a broad range of experiments embracing geology, marine biology, and studies of the water column, as well as tests of NEL-designed transducers and other sonar instruments. (Further details on *Trieste* are given in the 1960s section.)

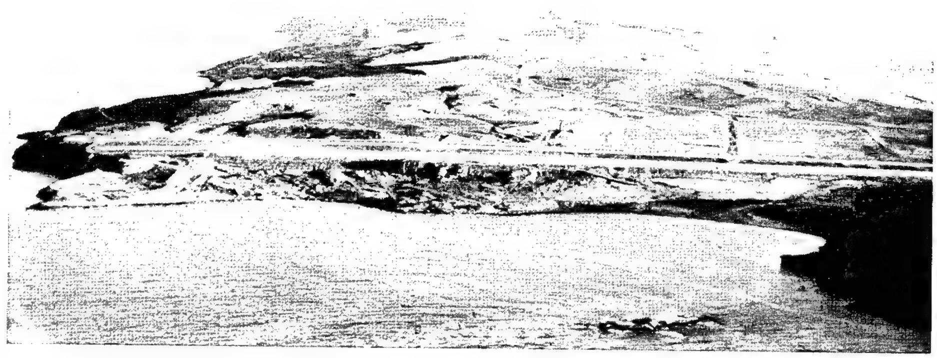
Trieste. *NEL used* Trieste *for broad-range experiments including geology, marine biology, and studies of the water column, as well as tests of NEL-designed transducers and other sonar instruments.*



Pasadena Management

As at San Diego, the management of Pasadena was shared by uniformed and civilian managers. In 1954, the Design and Production Department of NOTS Pasadena was merged into the Engineering Department at Inyokern and moved there. In 1955, the post office address and official name of the Station was changed from NOTS Inyokern to NOTS China Lake. Only the Underwater Ordnance Department remained at NOTS Pasadena.

Throughout the 1950s, NOTS Pasadena continued as an annex of China Lake and performed the major parts of such programs as torpedo research and development, underwater weapons testing and recovery operations, and the Polaris feasibility and testing program. As its work expanded throughout the decade, NOTS Pasadena grew to some 500 billets and took on the additional responsibilities of supervising range operations at sea in the same way that China Lake supervised weapons testing on its desert range.



San Clemente Island. Underwater test ranges off San Clemente Island were used for high-velocity, water-entry studies; large-scale underwater entry studies; and large-scale, underwater ballistics experiments. (1971 photo)

Pasadena Facilities

In 1951, NOTS Pasadena first began to use the Long Beach Test Range facilities (476 square miles of ocean) for air drops and surface firings. At the same time, NOTS Pasadena contracted with the Commandant, Eleventh Naval District (San Diego), to use the Navy's underwater test ranges at San Clemente Island. The San Clemente Island range continues to be used for high-velocity water-entry studies, large-scale underwater launch studies, and large-scale underwater ballistics experiments. The high cliffs and rapid drop-off of the ocean bottom allow underwater launches and air drops of weapon systems close to the shore. This capability simplifies coverage from many surveyed camera sites at different locations on the cliffs. San Clemente Island offers a combination of features including isolation from the public, accessibility for both the Navy laboratory and the Fleet, protected open ocean, climate, water depth, and available sites for data recording.

NOTS Pasadena: Advancing Torpedo Technology

Within less than a decade after its establishment, NOTS Pasadena became recognized for its knowledge and competence in applied research and component development of underwater weapons. In 1952, BuOrd assigned NOTS Pasadena general direction of aircraft-launched torpedoes and related accessories. Technical direction and design cognizance became terms of the day. This new responsibility added impetus to the trend toward development as the focus of activity, with research and testing oriented to support the development programs.

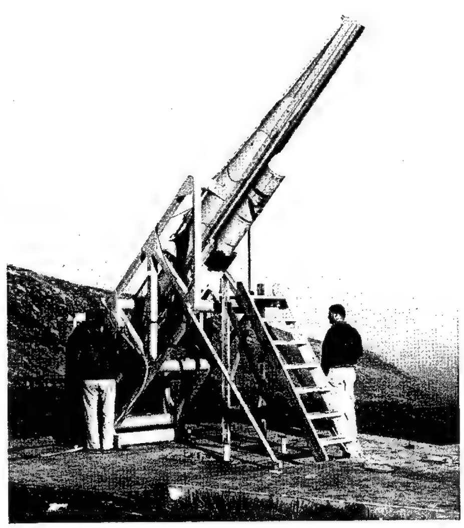
During this period, NOTS was assigned technical direction of projects such as the Mine Mk 24, Torpedo Mk 13 (as Petrel missile payloads), Torpedoes Mk 32, Mk 41, EX-8, Mk 43 Mods 0 and 1, and Mk 44.

Torpedo Mk 32

Even though the Korean conflict was primarily a land-based action, it brought increased activity to NOTS Pasadena. Torpedo work centered on the Mk 32, an acoustic homing torpedo that had been in experimental evaluation at Key West and had been shelved at the close of World War II. The responsibility of NOTS Underwater Ordnance Department was to reactivate, complete development, and carry the torpedo through to the point of fleet issue. Designed to operate below 100 feet at speeds to 11 knots, the Mk 32 was released to the Fleet in 1954.

Torpedo Mk 43 Mod 1

Developed by NOTS Pasadena and the Brush Development Company of Cleveland, Ohio, the Torpedo Mk 43 Mod 1 was the first lightweight, antisubmarine torpedo capable of being launched by helicopters, fixed-wing aircraft, and surface ships. Approximately 5000 of these torpedoes were produced from 1951 through 1959. This torpedo was withdrawn from fleet use after introduction of the Mk 44 torpedo.



Mk 43 Mod 1 torpedo at San Clemente Island, 1955.

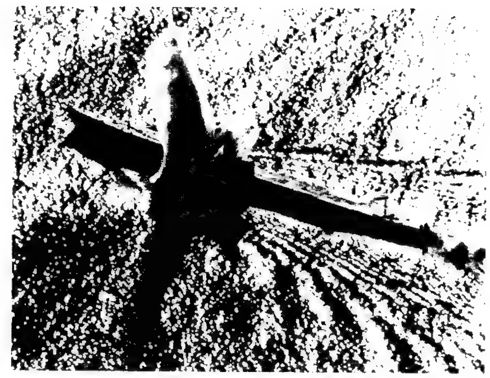
Torpedo Mk 44

The main work of NOTS Pasadena remained air-dropped torpedoes. But by the 1950s, the Navy no longer thought of lightweight torpedoes as primarily air-dropped ordnance to sink surface ships. The Soviet Union had a large fleet of submarines and practically no surface ships of note, so the orientation of lightweight torpedoes shifted toward ASW. Beginning in 1953, NOTS Pasadena and the General Electric Company of Pittsfield, Massachusetts, developed the electrically powered, acoustic homing Torpedo Mk 44. A distinctive feature of the Mk 44 was its active sonar, which enabled it to detect submarines as well as to home in on them once the target was localized. The Mk 44 went to the Fleet in 1958 and was initially deployed only from aircraft and surface ships. But late in the 1950s, NOTS Pasadena modified it to be used on helicopters and on the new thrown-ahead antisubmarine rocket (ASROC).

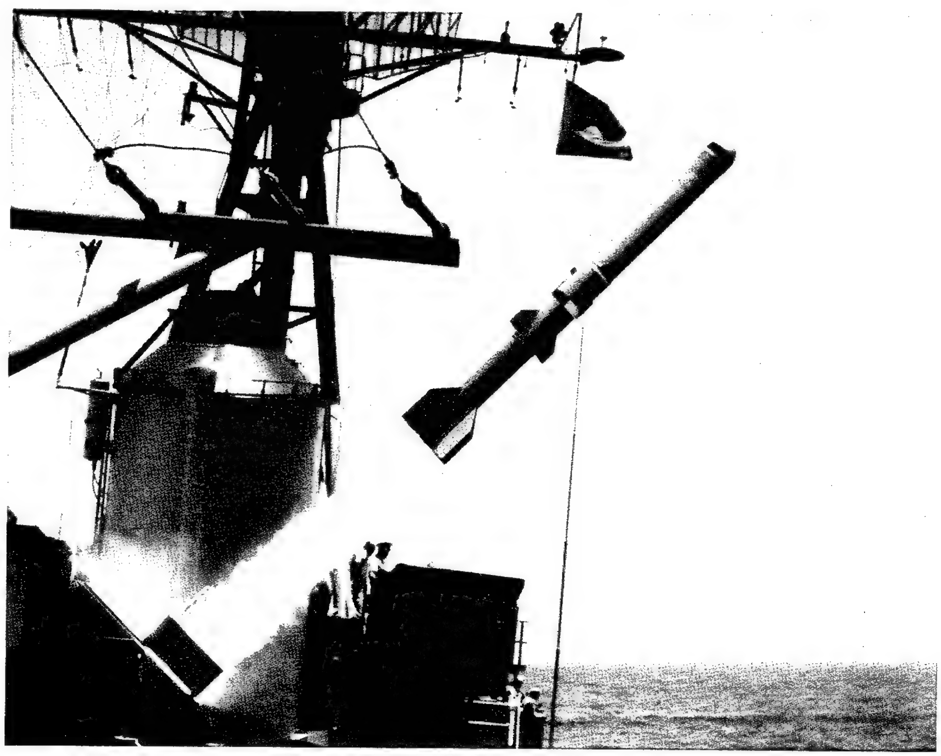
Antisubmarine Rocket (ASROC)

The success of Weapon A, a rocket-launched depth charge, paved the way for NOTS to develop a rocket-assisted torpedo, a quantum improvement in extending the power of ASW forces. Work on the Rocket Assisted Torpedo (RAT) began in the early 1950s and was proceeding when, in 1955, BuOrd asked its laboratories to assess the feasibility and desirability of firing a nuclear depth charge from ASW ships. NOTS did not want a weapon whose use would inflexibly escalate any conflict into nuclear war. Instead, it offered to develop a rocket-propelled weapon capable of either a nuclear depth charge or a lightweight acoustic homing torpedo, such as the Mk 44. BuOrd saw the advantages in such flexibility, and in 1956 began to sponsor work on the ASROC. NOTS Pasadena developed the systems, and NOTS China Lake built the rocket motor.

Successful "hit" of USS ex-Burrfish (SS 312) by ASROC-launched torpedo.



ASROC. A rocket-propelled weapon system, ASROC used a lightweight, acoustic homing torpedo or an alternate nuclear depth charge.



The ASROC's initial payload was a Mk 44 acoustic homing torpedo, and, in the summer of 1960, an ASROC-launched torpedo successfully "hit" the submarine USS ex-*Burrfish* (SS 312) at ranges of 2500 and then 4000 yards. The complete ASROC system consisted of a new sonar, a digital fire-control computer, an eight-cell launcher, and the ASROC rocket itself. The entire system, however much an evolution from previous NOTS work, established a number of "firsts." The rocket motor, for example, provided a unique variable thrust controller that allowed its range and course to be varied while in flight. In addition, the Mk 111 Fire Control Group was the first digital computer on a surface ship to control a major weapons system. The ASROC was installed on a broad range of cruisers, destroyers, and frigates. Subsequently, when the Mk 46 torpedo replaced the Mk 44, NOTS engineers developed a backfit program to allow the newer, more capable torpedo to be used with ASROC.

Polaris Launch System

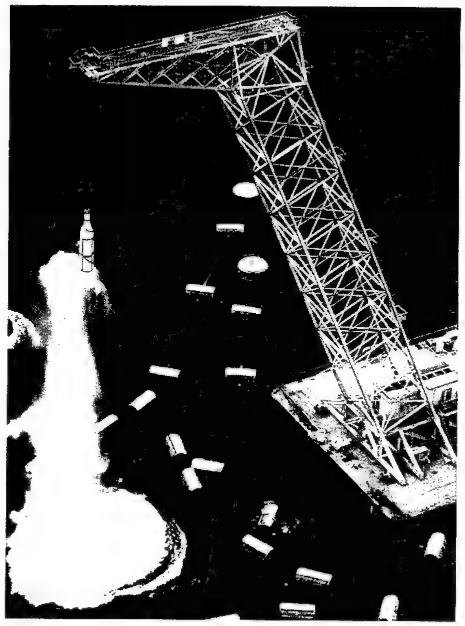
As an outgrowth of a 1955 Navy study entitled "Meeting the Threat of Surprise Attack," fleet ballistic missile systems, including submarine-launched missiles, were recommended to the Secretary of Defense, who authorized the development of this capability. CNO Admiral Arleigh Burke established the Special Project Office, administratively supported by BuOrd. Work began on the top priority Polaris missile in 1956. Four years later, the first Polaris submarine, USS *George Washington* (SSN 598), became operational.

At first, technical problems suggested that the Navy would never be able to launch guided missiles underwater. Rocket engines could not ignite underwater, and there was no other proven means of getting the missile to the surface. No information existed on how a missile launched underwater would function after being propelled through 50 or more feet of ocean. Would it remain on course? How would surface waves affect it? Could it be propelled high enough into the air for its engines to ignite? A project of this magnitude would have to be divided. As it turned out, Polaris research and development were divided into six main areas, each with a separate organization of Navy, government, contractor, and subcontractor personnel.

Lockheed was named prime contractor for the missile, but NOTS Pasadena worked mostly with Westinghouse, the contractor for the Polaris launcher and handling system. NOTS Pasadena had experience in underwater ballistics unequalled elsewhere in the Navy or in private industry. Thus, finding solutions for things such as launch depth, method of propelling the missile to the surface, safe underwater velocity for the missile as it reached the surface, maximum speed of the submarine, type of launch container, and the effect of surface waves on an underwater launch, all became part of NOTS Pasadena's role in Polaris development.

Operation Pop-Up began in 1957 in a section of Wilson Cove off San Clemente Island. NOTS engineers performed hundreds of test firings of redwood logs from an underwater launcher. Cameras were planted to photograph the motions of the dummy missiles in their progress through the water. By using varying amounts of air pressure, engineers studied how high out of the water each missile would pop.

The next phase of tests traded the redwood logs for steel cylinders filled with concrete. These tests were then followed by the launching of concrete-filled boiler plates. (Boiler plates were probable outside structures of the Polaris filled with concrete rather than actual missile parts.) Finally, the actual missile structure was established and proof-tested. For these tests, a special crane, named "Fishhook," was built to catch the missile at the apogee of its unpowered flight. The crane supported the rigging and take-up mechanism that reeled in a cable attached to the missile. As the missile traveled upward through the water and into the air, the cable would reel in at the same speed as the missile's upward travel. Since the missile was unpowered, and "popped up" by force of the ejection mechanism, the cable could be controlled to stop and "catch" the missile just before it began to fall back to the water.



"Fishhook." The Fishhook crane was used to test the Polaris missile at San Clemente Island.

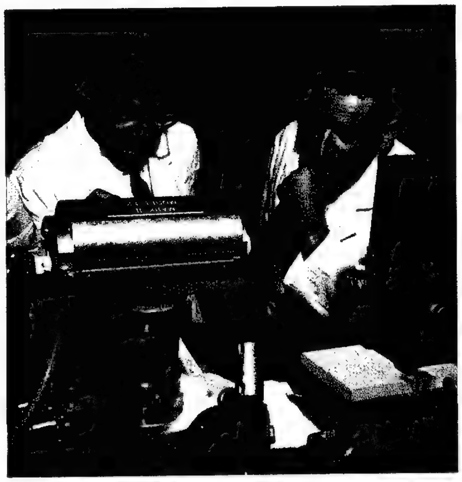
During much of this same time, simulated Polarises were being tested in the NOTS Hydroballistics Laboratory, a test facility in Pasadena that comprised an open-jet vertical water tunnel and a variable atmosphere tank (VAT). (NOTS' vertical water tunnel was one of only three such tunnels in existence; the other two were located in Minnesota and in Germany.) Under these laboratory conditions, 1/5-scale Polaris missiles were tested for flow characteristics and other hydrodynamic properties that could be applied to the full-scale underwater launchings.

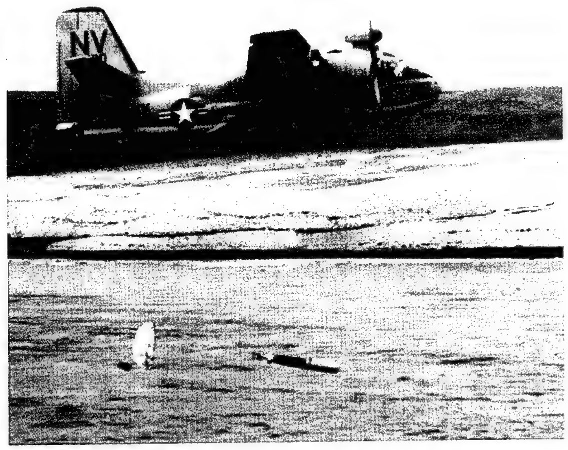
This series of tests, from laboratory to Fishhook, was completed on schedule in 1959, just as USS *George Washington* (SSBN 598), the Navy's first Polaris submarine, was about to be commissioned.

Polaris launching during Operation Pop-Up off San Clemente Island.

Meanwhile at San Diego, NEL scientists and engineers were addressing an equally critical issue for the Navy's submarine-launched deterrent, that of missile and submarine guidance. A ballistic missile submarine cannot surface to verify its position (and set the guidance system of its missiles) via celestial navigation. The only solution was to adopt an existing system of inertial navigation and miniaturize the system to fit inside each Polaris missile. Thus the missile could be programmed to reach a target at a set distance from the point of launch.

On 4 April 1960, a Polaris was successfully fired underwater from the test launcher off San Clemente Island. A few months later, *George Washington* fired its first Polaris, and a new era in naval warfare began.

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Introduction

The 1960s redefined the role and structure of the Navy laboratories. Beginning in 1961, Secretary of Defense McNamara directed reforms that centralized authority and systemized management of the laboratories. Authority was moved from the bureaus to the Chief of Naval Material. Management reforms, styled along corporate lines, linked planning and budgeting.

Deputy Director of Defense Research and Engineering, Dr. Chalmers Sherwin, recommended that the laboratories be consolidated into self-contained "core laboratories" that could perform work across the entire R&D spectrum.

Rapidly changing technology also changed the scope of work done at the laboratories. Advances in solid-state electronics and digital circuitry, for example, offered a quantum increase in reliability and computing. The growing need for successively higher levels of command to obtain reliable combat information and to direct forces called for new systems in command control; to meet that need, NEL engineers developed the Command Ship Data System (CSDS), the Fleet Flag Data System (FFDS), and the Integrated Flagship Data System (IFDS). Lasers emerged as a new technology, and NEL focused on the potential of lasers for communications. Ocean technology developed rapidly in the 1960s; keeping pace with that development, NEL participated in several historic missions of the bathyscaph *Trieste*. NEL and NOTS also participated in Sealab II, and NOTS developed several vehicles for manned and unmanned undersea operations. Also during the sixties, the advent of nuclear submarines placed new demands on the torpedo program; to meet those demands, NOTS developed the Mk 46.

On 1 July 1967, mergers produced a dramatic reorganization of Navy laboratories. NOTS Pasadena became the Naval Undersea Warfare Center (NUWC), with a branch in San Diego. Also, that portion of NEL devoted to undersea research was made a part of the newly established NUWC branch in San Diego. NEL, in line with its new mission, was renamed the Naval Command Control and Communications Laboratory Center (NCCCLC); within a year, NCCCLC became the Naval Electronics Laboratory Center (NELC).

The McNamara Era

Redefining the Role of Navy Laboratories

Beginning in the 1960s, President Kennedy's Defense Secretary, Robert McNamara, directed a series of reforms that eventually changed the role and structure of the Navy's laboratories. In brief, the McNamara reforms attempted to reorganize DoD laboratories under corporate lines, but they also sought to curtail interservice rivalry and reduce duplication of effort by concentrating more authority in the Office of the Secretary of Defense (OSD).

Upon taking office in 1961, Secretary McNamara submitted a long list of questions to his subordinates. Question 97 ran as follows: "Advise me on ways in which to improve the operations of the in-house laboratories." The Task 97 Action Group reported that the laboratories played a vital role in national security:

- They could investigate rapidly changing technologies for their applicability to military problems. Simultaneously, they could bring military needs to the attention of the general scientific and technical community.
- They enabled the services to be "smart buyers" of contract R&D.
- They managed and helped manage weapons systems development and test programs.
- They developed a cadre of technically proficient military officers necessary in the modern armed forces.

Funding was just one area cited for improvement. The Task 97 Action Group reported that technical directors wanted more discretionary funding. Navy laboratories depended too much on bureau sponsors, were losing touch with the cutting edge of science, and were having troubles attracting top scientists. Obtaining sponsor support required excessive time from technical personnel. Managers complained that laboratories were being turned into "job shops" and were spending more time managing contracted work rather than researching challenging and broadly defined assignments.

Task 97 recommendations led the Navy to establish independent research (IR) as a budget line item in 1964. Similarly, in 1963, the bureaus had been directed to establish independent exploratory development (IED) as a budget line item. The laboratories were authorized to initiate certain exploratory development on their own, without having to obtain bureau approval. Both BuShips and BuWeps established IED programs in 1964, directing that IED funds were to be used to support work in assigned mission areas.

Core Laboratories: Centers of Excellence

The Navy continued to look for various ways to improve the laboratories. In 1964, the Deputy Director of Defense Research and Engineering, Dr. Chalmers Sherwin, proposed a series of sweeping reforms. Key recommendations included the following: (1) group the laboratories into functional centers with broad military problem-oriented missions and satellite laboratories reporting to the laboratory centers; (2) consolidate the 13 existing laboratories into 9 new centers, all placed under a Director of Navy Laboratories (DNL), who would allocate manpower, facilities, supporting funds, and funding for the core mission(s) of each center; (3) place each laboratory under a civilian scientist or engineer reporting to the Assistant Secretary for R&D; (4) perform work in each laboratory across the entire spectrum of basic research, applied research, systems design and fabrication, in addition to engineering design of systems; (5) divide funding equally between the laboratories' "core" program (that is, block-funded independent of sponsors in Washington) and programs that were "customer-funded" (that is, paid for specifically by Washington-based sponsors).

As the idea of "core laboratories" developed, a technical center was defined as a self-contained laboratory of more than 1000 specialists who could perform basic research, develop feasibility models, and oversee systems developments.

Director of Navy Laboratories (DNL)

On 20 December 1965, the position of Director of Navy Laboratories was established. Although the charter granted DNL control of the in-house exploratory development program, the charter did not provide DNL with funds to control this portion of the budget. The material bureaus (and their successors, the systems commands) retained control of most of this budget. In reality, the Office of DNL could not materially influence technical programs because the programs were not funded by DNL. Hence, DNL became more a coordinator of research administration than a research director with line authority.

From Bureau to Chief of Naval Material (CNM) Management

On 15 March 1966, responsibility for the management of the bureau laboratories was moved from the bureaus to the Chief of Naval Material (CNM), an admiral reporting to CNO. This move reflected McNamara's view that the functions of the laboratories should be broadened beyond the interests of the bureaus. On the one hand, the laboratories should have more discretionary funding, so that they would not depend entirely on sponsors. On the other hand, they needed more supervision, so the services and the material agencies within the services would not duplicate each other's work. McNamara's management team had several rationales for the transfer of Navy laboratories from the sponsoring bureaus to CNM. First, they thought that shifting the laboratories from their previous bureau sponsors to an independent authority would free the laboratories from overly narrow concerns. Second, centralized control would eliminate duplication of effort and provide OSD with greater oversight. Direct military supervision of the laboratories remained in the form of CNM. However, the long-standing sponsor-project manager relationships endured.

The bureaus were replaced by a new series of systems commands, SYSCOMS, whose heads reported to CNM, who reported directly to the CNO, rather than directly to the Secretary of the Navy. Now, the uniformed head of the Navy, CNO, had full command authority over commands, naval districts, and the former bureaus. The four material bureaus became six systems commands: the Ordnance Systems Command, Sea Systems Command, Supply Systems Command, Electronic Systems Command, Air Systems Command, and Facilities Engineering Command.

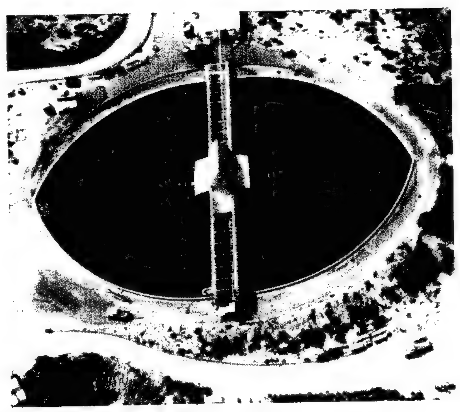
Naval Industrial Fund (NIF)

The effort to impose corporate management-style methods carried over into funding. Among the themes most prominent in the studies of Navy laboratories during the 1960s was that the funding of R&D was fragmented and encouraged duplication and excessive management. Severe restrictions on reprogramming (i.e., shifting funds appropriated for one purpose to another project) and uncertainties over funding from year to year contributed to waste, delay, and rigid financial controls. To remedy these problems, the Navy converted the laboratories to the Navy Industrial Fund (NIF). Customers were charged the full cost of products and services. These costs, compared with industry, provided a measure of the laboratories' efficiency. Originally, the NIF system developed at docks and yards, where labor and material charges were paid for by the districts of which they were a part. For the laboratories, NIF was to make them more businesslike since true costs could be estimated from specific line items instead of general overhead.

NEL Growth

The late 1950s and the first half of the 1960s saw a steady growth in the size of NEL. By 1965, NEL had grown to more than 1500 civilian billets and 150 military, about 300 above the low point of the mid-1950s (between 1100 and 1200). NEL's budget quadrupled from $10 million annually to over $40 million. Since staffing did not rise on the same scale as spending, the increased volume of projects required more contracting of work.

During this time, NEL's mission encompassed three technology areas: (1) undersea technology, including underwater acoustics, surveillance, mine warfare, submarine navigation, and physical oceanography; (2) electromagnetics, including propagation research, electronic warfare, satellite communications, VLF radio navigation, and radars; and (3) computer systems development and computer languages, including data processing in general but also shipboard computer-driven information and command and control systems.



TRANSDEC. Opened in 1964, this freshwater anechoic pool allowed NEL engineers to make extremely accurate measurements of transducers.

New NEL Facilities

Transducer Evaluation Center (TRANSDEC)

In 1960, the owner of Sweetwater Lake, the California Water and Telephone Company, began to lower the level of the lake. To continue using the calibration station there, NEL would have had to relocate all its buildings, so in 1962, the laboratory began building a freshwater anechoic pool on the ocean side of Catalina Boulevard.

The original concept for the Transducer Evaluation Center (TRANSDEC) was developed by NEL employee Charles E. Green. Green, holder of several patents on the design of the pool, began experimenting with the basic principle of TRANSDEC in the early 1950s. He proposed use of his design for a man-made elliptical pool to replace the facilities at Sweetwater Lake. Since no suitable natural lake was available, Green's design seemed ideal. It also eliminated problems of off-station management, security, and transportation.

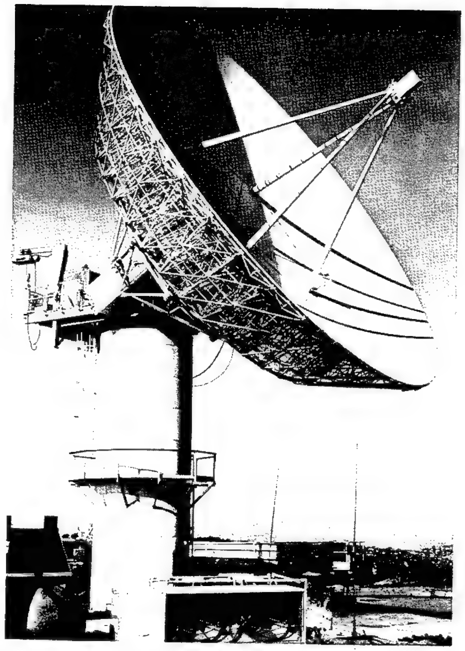
Opened in 1964, TRANSDEC achieved what had never been possible at Sweetwater Lake, a simulation of an "infinite" expanse of water free from echoes (that is, anechoic). The design eliminated

all extraneous man-made or natural biologic noises and permitted precise control of surface and subsurface conditions. NEL engineers could make extremely accurate measurements of transducers used in their systems.

For his part in TRANSDEC, Green was awarded a Presidential Citation in 1964 by President Lyndon B. Johnson.

Parabolic Radio Telescope

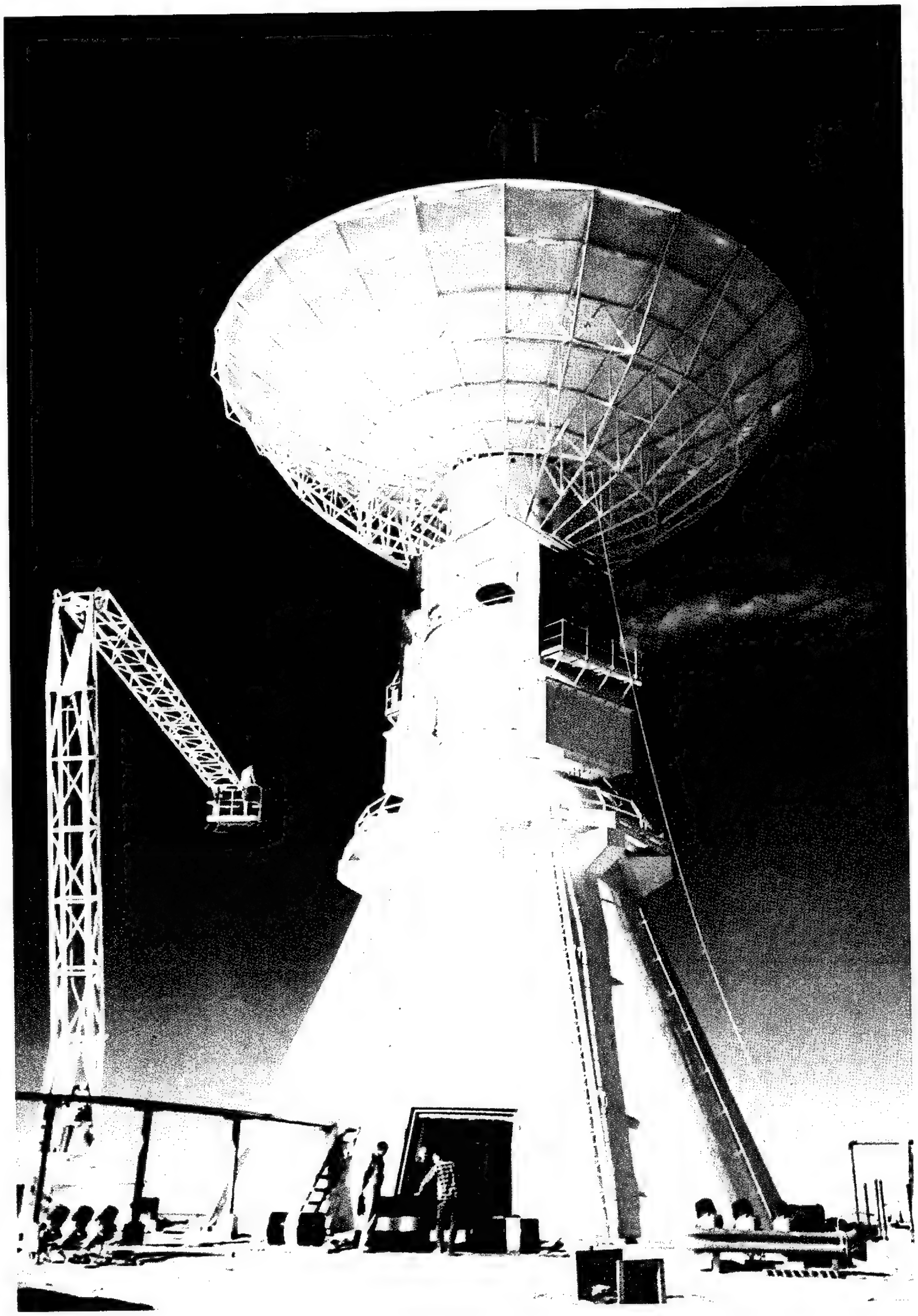
In 1961, to support the satellite communications programs and radio physics research in general, NEL built on Point Loma a 60-foot solid parabolic antenna reflector on a reinforced concrete tower. NEL also built an adjacent 28-foot reflector. Both the big dish and the 28-foot reflector were used in super-high frequency experiments in 1964, the first of a long series of such experiments. During the Vietnam War, the 60-foot antenna also served as a relay in a secure data system.



Parabolic Radio Telescope. This 60-foot-diameter, solid parabolic antenna reflector was built to support satellite communications programs and radio physics research.

Astro-Geophysical Observatory

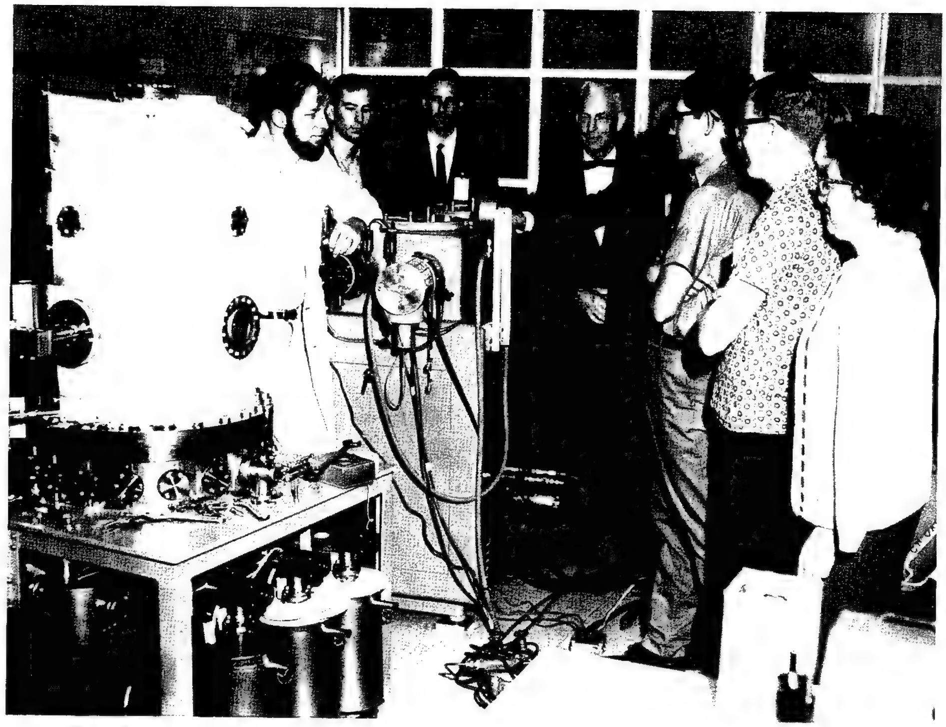
To support Navy and Air Force communications satellite programs with research in propagation and ionospheric forecasting, NEL built an astro-geophysical observatory 65 miles east of San Diego at La Posta, California. Begun in May 1964, the observatory was completed a little over a year later. Unlike the mirror radio telescope on Point Loma, the La Posta mirror antenna could transmit as well as receive. Located atop a 3900-foot site in the Laguna Mountains about 6 miles northeast of Campo, California, the observatory was operated jointly with the Air Force and used in joint studies with a similar structure built by NRL at Waldorf, Maryland. The observatory had to be located in an unpopulated area that was free of hazardous radiated energy levels and that provided an environment for ultrasensitive reception, free from noise and interference. During the 1960s, the observatory played a major role in solar radio mapping, studies of environmental disturbances, and development of a solar optical videometer for microwave research.



Astro-Geophysical Observatory, La Posta, CA. The mirror antenna at La Posta supported research in propagation and ionospheric forecasting.

Microelectronics Laboratory

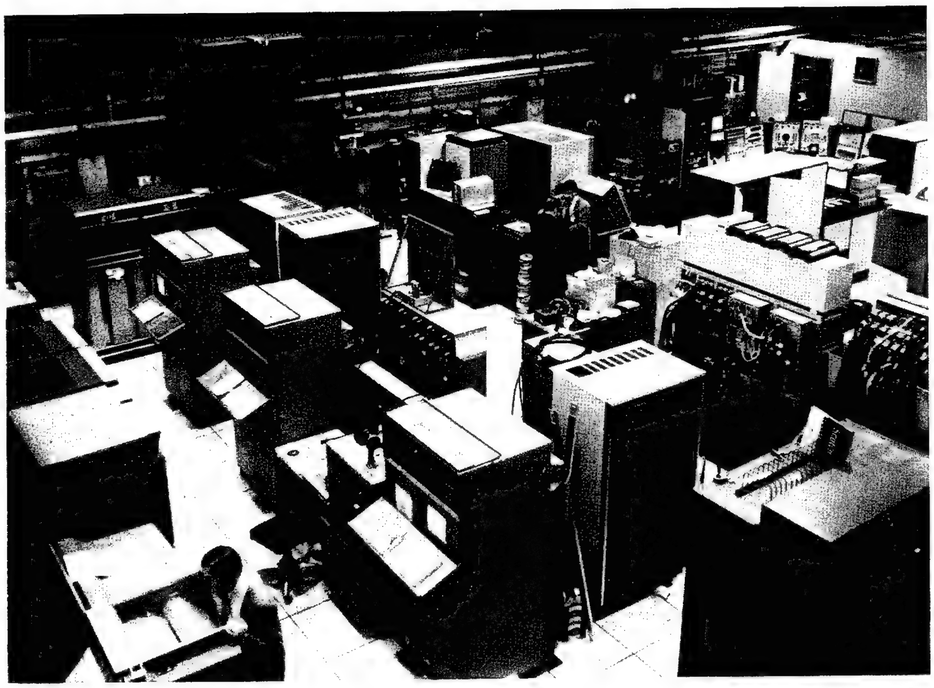
During the mid-1960s, NEL converted a portion of Battery Ashburn into a secure communications laboratory and another portion into a microelectronics laboratory that would support a wide range of systems using the new digital technology. Already naturally shielded from electromagnetic interference, the heavy concrete of Battery Ashburn continues to provide a vibration-free environment with a naturally stable ambient temperature. A laminar-flow air-filtering system gives the laboratory several "clean rooms" in which the air is kept free from particles as small as 0.3 micron.



Microelectronics Laboratory, 1968. Dr. Carl Zeisse (far left) describes the laboratory's unique capabilities to visitors.

Applied Systems Development and Evaluation Center (ASDEC)

During the 1960s, NEL built the Applied Systems Development and Evaluation Center (ASDEC), the first Navy facility specifically intended to accommodate systems developments in the new era of computer technology. A 5400-square-foot open-shop facility, ASDEC was a full-scale mockup of a shipboard combat information center, consisting of interactive displays, data-processing equipment, and communications. ASDEC was located in wing 1 of NEL's main building. Built around an NTDS-like system, ASDEC was linked to sensor systems that provided live radar, live digitized data, and live voice information. ASDEC served as a general purpose testbed where computer-based data systems could be assembled, programmed, and debugged in settings similar to their intended operational use. Although real sensor data were sometimes used, most of the sensor inputs came from various simulators developed by NEL scientists. By 1970, ASDEC was increasingly used for software development.



ASDEC. This 5400-square-foot facility provided a full-scale mockup of a shipboard combat information center.

NOTS Pasadena Growth

During the early 1960s, NOTS Pasadena had approximately 1000 people—800 of them civilians, a few officers, and nearly 200 sailors. In 1965, its annual budget exceeded $41 million. With its proximity to Caltech, the University of Southern California, the Claremont Colleges, and UCLA, NOTS Pasadena encouraged its staff to pursue graduate studies in work-related fields and to use nearby academic expertise through research contracts in hydrodynamics, signal processing, and mathematics. NOTS Pasadena and NEL had begun to have closer contacts during the early 1960s. Representatives from both organizations participated in joint working groups as well as panels concerned with technical issues such as sonar and ASW weapons systems and with administrative issues such as civil service regulations and military construction.

Reorganization

By 1966, the Naval Material Command concluded that Pasadena facilities were no longer adequate to support its missions. Also, a Defense Science Board committee had recommended that the Navy establish a development center for ASW-surface weapons. The Navy studied various sites, including Los Alamitos, Santa Barbara, and San Diego, for a new West Coast undersea center.

Meanwhile, the decision was made to consolidate the 15 Navy laboratories into 9. Laboratories at Corona, California; Brooklyn, New York; and San Francisco, California, were shut down. Elsewhere, mission assignments were realigned, and names were changed to reflect the new roles given remaining laboratories. NOTS China Lake merged with the Corona laboratory and became the Naval Weapons Center (NWC).

Naval Undersea Warfare Center (NUWC)

On 1 July 1967, NOTS Pasadena (with its specialty in underwater ordnance) merged with NEL's undersea technology element to form the Naval Undersea Warfare Center (NUWC). In October 1967, the Marine Biosciences Facility at Point Mugu, CA, was transferred to NUWC from the Naval Missile Center. The newly established Center was to be the prototype of the core laboratory proposed by Dr. Chalmers Sherwin and others. Dr. William McLean, Technical Director of NOTS China Lake and famed for inventing the Sidewinder antiaircraft missile, became the first Technical Director of NUWC. Douglas Wilcox, Assistant and later Associate Technical Director at Pasadena, continued as senior civilian at NUWC Pasadena and reported directly to Dr. McLean, who preferred to temporarily keep his own office at China Lake. Captain G. H. Lowe, formerly Officer in Charge of NOTS Pasadena for 4 years and Commander of NOTS China Lake for 5 months, was selected as Commanding Officer of NUWC.

The San Diego branch of NUWC used existing NEL facilities, and most NEL researchers who joined the NUWC staff remained in their same offices. The head of what had been NEL's Undersea Technology Department, Dr. Donald Wilson, became head of the San Diego branch of NUWC and moved from Building 33 Topside to the bayfront area. On 1 July 1968, NUWC's official headquarters transferred from Pasadena to San Diego. The merger of ASW groups made sense: With digitized data certain to play a greater role in ASW, computerized systems would have to "talk" to one another. By putting scientists and engineers in these related fields together, interfaces between submarine detection systems and antisubmarine weapons systems would be easier to develop.

The reorganization brought with it additional recognition for ASW and ocean engineering. Recognition led to increased sponsorship and military construction funds. In 1969, the military systems analysis function of the Naval Radiological Defense Laboratory (NRDL) was also assigned to the Center when NRDL was disestablished.

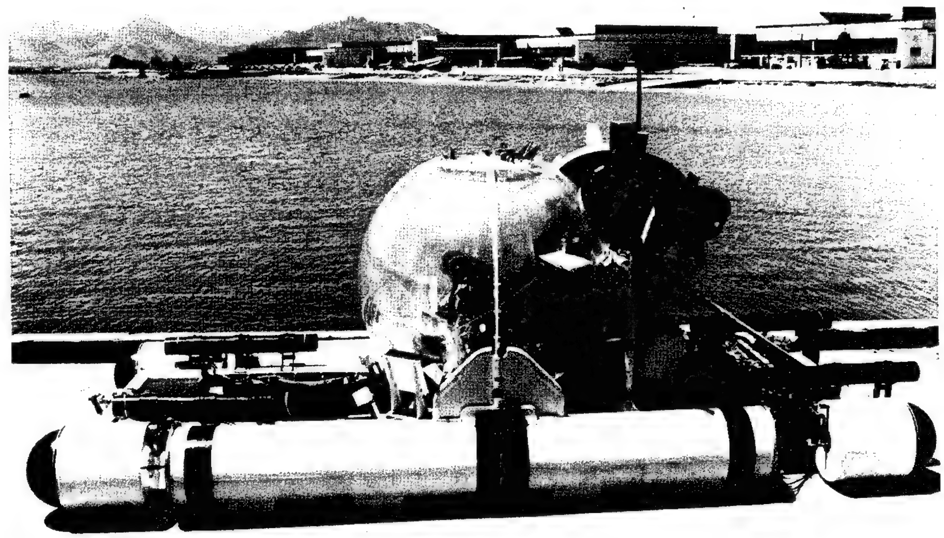
Dr. McLean decided to establish a satellite NUWC laboratory in Hawaii because its surrounding warm waters would provide year-round access for R&D in two areas of particular interest to him: marine biosystems and manned submersibles. In 1967, representatives from NUWC chose a site on Oahu adjacent to the Marine Corps Air Station at Kaneohe Bay. At the time, the real estate consisted of one unused hangar and a few acres with waterfront access.

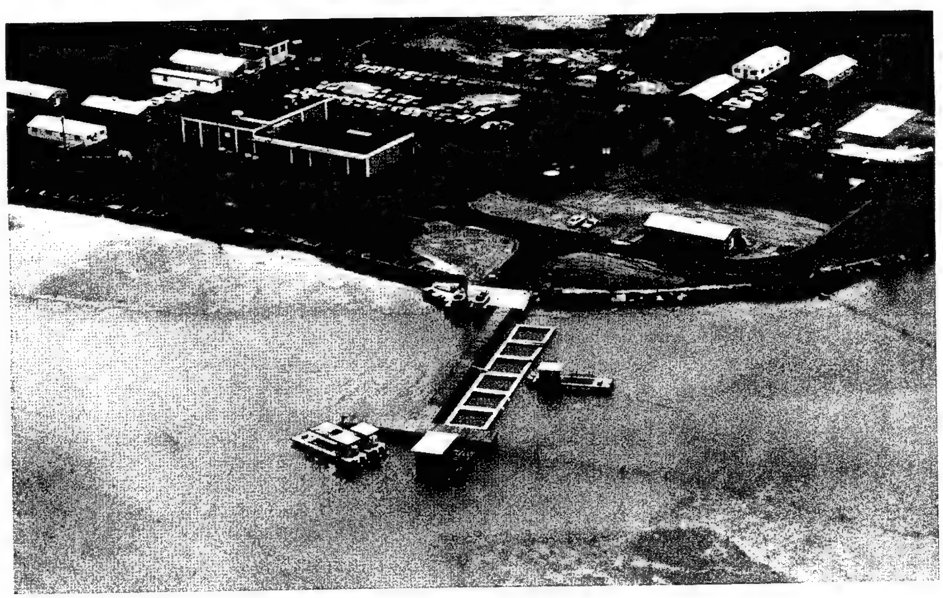
Originally staffed by former "China Lakers," the facility was officially dedicated in 1968. Jesse Burkes, a retired Navy Captain with the title of Area Director, headed a staff

of 35. Over the years, the Hawaii laboratory increased in size and stature, growing to 25 acres and nearly 200 employees by the time it celebrated its 20th anniversary.

Among the manned submersibles developed or tested in Hawaii were Dr. McLean's *Hikin*, the original two-man acrylic submarine and the follow-on improved acrylic, two-man *Makakai* (Hawaiian for "eye of the sea"), a 600-foot Navy certified submersible designed for oceanographers and marine biologists to observe the sea directly. Like the parent laboratory, the Hawaii laboratory was to become the site for significant research in advanced remotely operated vehicles (ROVs) and work systems packages: The Remote Unmanned Work System (RUWS) was a technology development program and the forerunner to the Advanced Tethered Vehicle (ATV). Both programs will be discussed later.

The Makakai *two-man submersible. The acrylic sphere afforded the operator and passenger an unobstructed, panoramic view of the outside surroundings, an enormous advantage over viewports in traditional submersibles.*





Hawaii Laboratory. NUWC established the Hawaii laboratory in 1967 to pursue work in marine biosystems and manned submersibles. (1971 photo)

New Name for NUWC

The name "Naval Undersea Warfare Center," though it explained the rationale for the new laboratory in San Diego, proved a liability in the political climate of the late 1960s. Finding their invitations to conferences drying up and campus recruitment declining, NUWC scientists and engineers blamed their institutional affiliation. Their concern led to a new name for the Center. In 1969, NUWC was renamed the Naval Undersea Research and Development Center (NURDC).

New Names for NEL

In keeping with the reorganization program of 1967, NEL was formally renamed the Naval Command Control and Communications Laboratory Center (NCCCLC). NEL's Technical Director, Dr. Ralph Christensen, and Commanding Officer, Captain William Boehm, continued at NCCCLC. The new name for the laboratory seemed cumbersome and never gained full acceptance. Hence, in 1968, the name was changed to the Naval Electronics Laboratory Center (NELC).

Work at NELC was to concentrate on command control, communications, surveillance, and related programs. NELC was to assume its new role as a "center of excellence" in digital data links, satellite communications, electronic warfare, tactical data systems, radio, radar, and electronic displays.

Fiscal Year 1969 saw completion of the transfer from NELC of all facilities and equipment related to the undersea research functions. NUWC/NURDC received the Point Loma waterfront property it had occupied up to that time as a tenant under an Intraservice Support Agreement with NELC. By mutual agreement, NELC further transferred those permanently installed research facilities located within the NELC area but used exclusively by NUWC/NURDC. These were the Arctic Research Facility, the Transducer Evaluation Center (TRANSDEC), and the Marine Bio-Acoustic Experimental Facility. In 1969, Battery Whistler was formally renamed the Arctic Submarine Laboratory, and Dr. Waldo Lyon was named its first Director.

New Systems and Research

Submarine Broadcast System

With the success of the Polaris submarine program, the importance of strategic submarine communications increased. Beginning in the early 1960s, NEL and its successors played a central role in the development of Verdin, a VLF/LF communications system designed to provide up to four channels of information for deeply submerged ballistic-missile submarines.

Work on improving VLF radio for the submarine broadcast system continued during the 1960s and 1970s. Basic studies of ionospheric propagation were central to this work, and NEL established several outstations during the 1960s to support studies of long-range radio transmission. The laboratory conducted these studies at sites located at Sentinel, Arizona; Thule AFB, Greenland; Phoakuloa, Hawaii; and Fairbanks, Alaska. Each location had VLF transmitters and receivers. Their work was "sounding," that is, transmitting VLF signals into the ionosphere at different locations to determine atmospheric interference with VLF transmissions. For example, the Fairbanks,

Alaska, site studied the ionosphere during periods when the phenomenon of the Northern Lights (aurora borealis) was most active.

In 1964, scientists developed a technique for separating round-the-world VLF signals from short-path signals at the same frequencies. By 1965, other NEL scientists focusing on the earth's geomagnetic fields had developed new fundamental concepts of modal propagation in a waveguide that had direct applications to the Verdin system. (NOSC today is responsible for improving and enhancing the Verdin system, which includes a fixed shore-based transmitting system, an airborne transmitting system, a processing system, and an automated control system—the combination providing an automated worldwide broadcast system.)

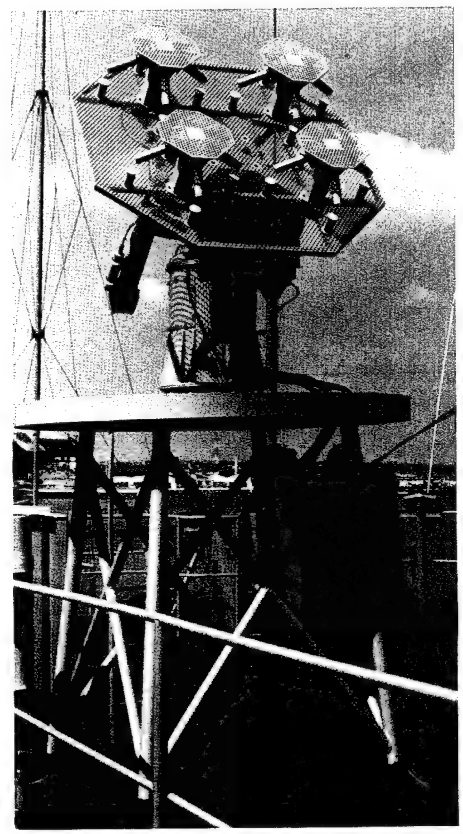
Communications

In Project MAILBUOY in 1962, NEL developed the first UHF communication system. The program continued during 1963 into Project REDGLARE in which a UHF communications repeater in a rocket successfully passed teletype, voice, and facsimile data from ship to shore. Although too costly to serve as a communications system, REDGLARE demonstrated the feasibility of long-range communications through a space-based linkup. As soon as satellites became reliable and affordable in the early 1960s, NEL began work on satellite-based communications systems.

Satellite Communications/ Shipboard Satellite Terminal

NEL radio physicists conducted their first experiments with communications in space in 1960, using the Echo 1 satellite. They continued to experiment with higher frequencies, notably super high frequency (SHF), aboard the communications satellites that became widespread in the decade that followed. The data derived from these tests enabled NEL and others to develop antennas and terminals, so that by 1965 the Navy could operate a satellite communications system for over-the-horizon (OTH) communications.

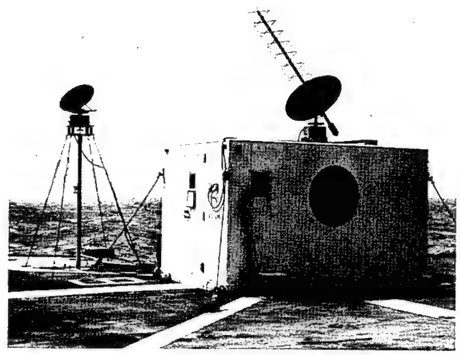
In 1968, NELC designed a shipboard satellite terminal for the cruiser USS *Providence* (CG 6). In 1969, tests aboard the cruiser off Tahiti successfully demonstrated the feasibility of satellite relay of fleet multichannel broadcasts, which were picked up on portable equipment installed aboard *Providence.* The choice of Tahiti, a zone of poor high-frequency reception, showed that the relatively low-cost portable equipment NELC had developed could meet the needs of the Fleet. The equipment on *Providence* was installed by NELC personnel and served as a base for the design of terminals on six ships involved in a Fleet Operational Investigation. The exercise was held in the Atlantic and was the Navy's first large-scale test of satellite communications. At the same time as the exercise was held, satellite transmissions between NELC and the carrier USS *Independence* (CV 62) at Norfolk, Virginia, demonstrated the feasibility of long-distance relay of tactical data via satellite.



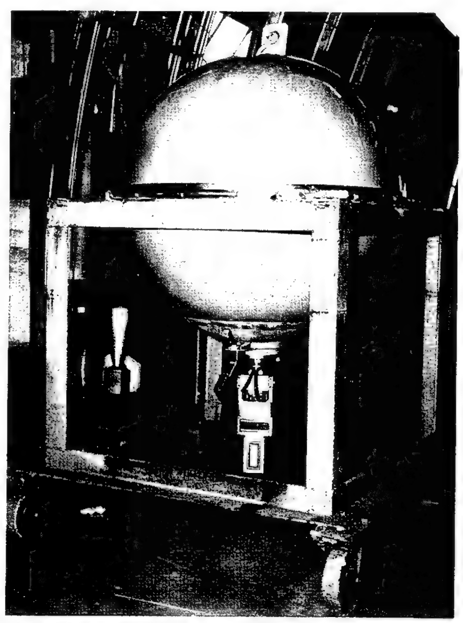
Satellite communications. Shipboard satellite terminal aboard USS Providence *(CG 6).*

Apollo Recovery Exercise

In 1969, NELC successfully applied satellite communications technology to the National Aeronautics and Space Administration's (NASA's) Project Apollo recovery operations. Previously, during Apollo 8 in 1968, atmospheric interference disrupted radio communications. As a result, NASA, in January 1969, asked NELC to develop satellite communications gear to support UHF communications during future Apollo missions, including the one scheduled to land a man on the moon later that summer. Within a month, NELC researchers developed a portable terminal that was flown to Norfolk, Virginia, and deployed aboard the recovery ship, USS *Guadalcanal* (LPH 7). NELC engineers operated the terminal during Apollo 9 as the primary command control circuit between Mission Control at Houston and the recovery areas. NELC engineers operated the terminal during Apollo 10 and Apollo 11 and then transferred the terminal to NASA.



Apollo recovery exercise. Portable terminal aboard the recovery ship, USS Guadalcanal *(LPH 7).*



AN/SQQ-16 towed array. The AN-SQQ-16 was one of the first portable, towed, passive sonars that permitted very-high-resolution target classification.

Sonar Systems

During the 1960s, ocean surveillance research focused on mobile or tactical surveillance, that is, hull-mounted or towed-array sonars used by ASW craft. In 1964, NEL developed the AN/SQQ-16 towed array, one of the first portable, towed, passive sonars that permitted very-high-resolution target classification.

NEL also worked on long-range active detection systems. The research trend was then toward higher power and lower frequencies, but the size, power requirements, and cost of equipment were considerable obstacles. More successful efforts were to harness the power of computing to process signals more efficiently, to raise the "signal-to-noise ratio" (the ability of a sonar to discriminate a target echo from the ambient noise of the oceans), and to handle the resulting data so that ships could use the data operationally.

Equally significant accomplishments were in the field of transducer design, notably transducer modules with their own power amplifiers. NEL acousticians developed theories to predict the performance of transducers in different configurations and in different oceanic conditions and environments.

Radar

By the 1960s, NEL's work in radar had shifted from system development to the interpretation of radar echoes. The goal of this work was to increase detection rates through the analysis of low-level echoes. Signal forming and processing techniques seemed the most promising methods of enhancing radar performance and achieving the necessary correlation function. Electronic beamforming by computer-directed arrays was accepted as the most direct answer to the mechanical problem of stabilizing and rotating the large search radars in use by the late 1950s.

Arctic Submarine Warfare

The success of the transpolar cruises of *Nautilus* and other submarines in the late 1950s brought recognition to NEL and to Dr. Waldo Lyon. In April 1962, in an impressive ceremony at the White House, President Kennedy awarded the Distinguished Federal Civilian Service medal to Dr. Lyon. Mrs. Lyon accepted for her husband, who was absent on a "confidential mission" for the Navy. The timing was fortuitous for Dr. Lyon because he preferred to shun the limelight and go quietly about his work. Dr. Lyon received a certificate hailing him "for a devotion to a concept in which he never lost faith and for his tenacity in pursuing it against formidable technical problems and in the face of discouraging reverses...."

Although much less publicized than the cruise by *Nautilus* 2 years earlier, the cruise of USS *Sargo* (SSN 583) in 1960 proved to be even more significant operationally, since it was the first winter deployment under the polar ice and one of the most demanding. The submarine both entered and left the Arctic via the shallow Bering and Chukchi seas. *Sargo* sailed more than 6000 miles under the ice and surfaced 20 times in the worst imaginable conditions. On 9 February 1960, *Sargo* surfaced at the North Pole.

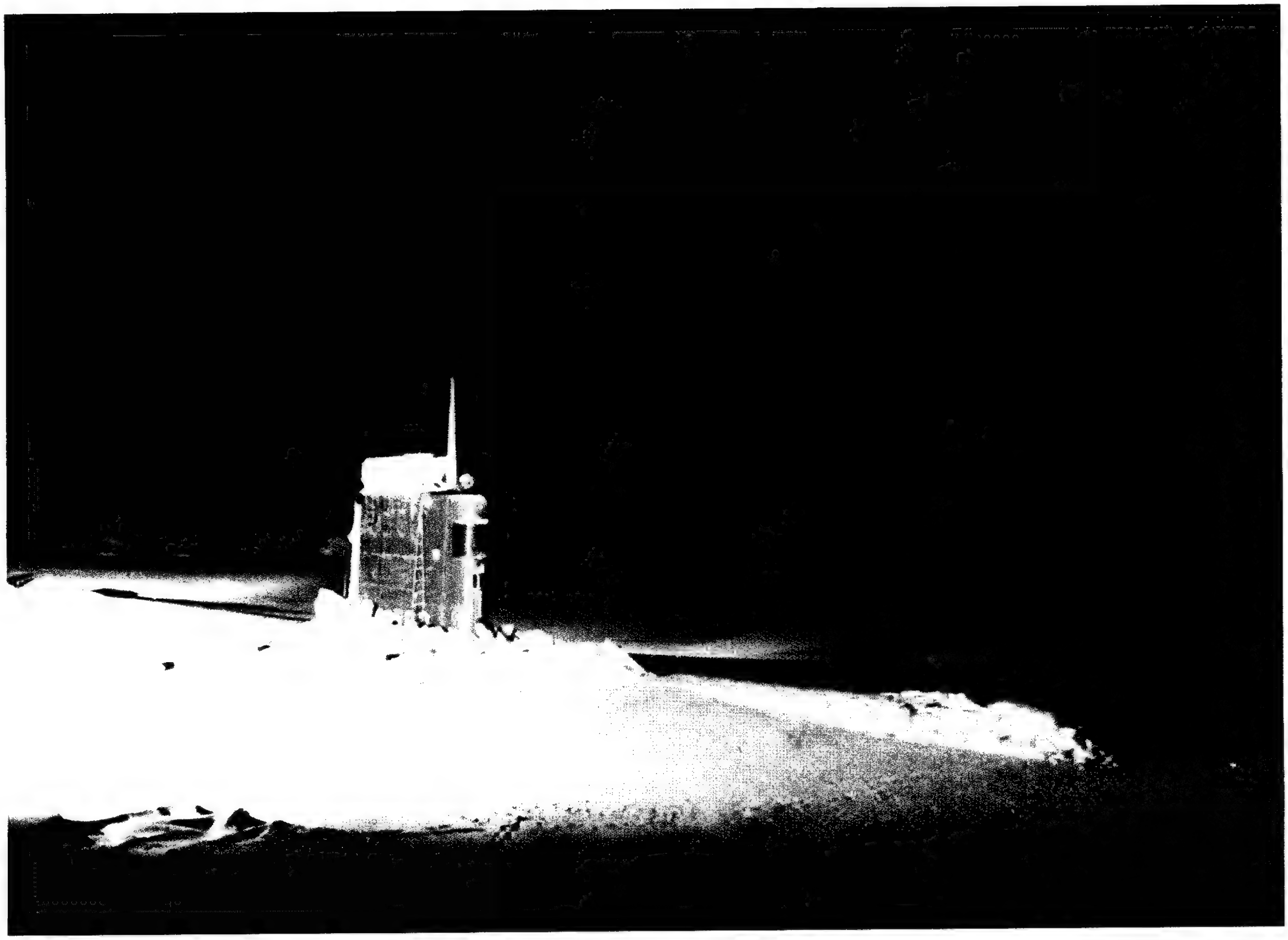
The achievement of *Sargo* would have been impossible but for the seamanship of her navigators and the experimental iceberg detector sonar developed by NEL's High-Resolution Sonar Division and tested by NEL sonar specialists aboard *Sargo* on its 31-day voyage. The iceberg detector detected ice keels even when the nuclear-powered submarine was moving at full speed.

Iceberg detection system developments culminated in the AN/BQS-8 acoustic ice suite that provided the all-around visibility needed for under-ice operations. NEL directed arctic tests of the prototype in the summer of 1962, and CNO approved the ice suite for service use. Production contracts were immediately issued. NEL continued to monitor the contracts, but manufacture passed to contractors and maintenance went to other Navy engineering facilities.

The same basic principles used to develop under-ice sonars were applied to navigation systems for the Arctic. NEL scientists developed an acoustic transponder to serve as an under-ice reference point. Either nuclear- or battery-powered, the transponder was anchored to the bottom of the Arctic Ocean at entrances to known hazardous passages and at intervals along most transarctic routes. The device was first tested in the summer of 1964 and was later used in arctic cruises.

Once Navy submarines had successfully crossed the North Pole, interest in arctic submarine activities faded. The relative lack of interest in arctic submarine warfare after the early 1960s reflected a general view that the important navigation problems of the region had been identified, studied, and filed. Submarine and icebreaker cruises in the Arctic continued but at a reduced rate.

President Kennedy and Mrs. Waldo Lyon at the White House, April 1962. Mrs. Lyon accepted the Distinguished Federal Civilian Service medal on behalf of her husband, Dr. Waldo Lyon.



USS Sargo *(SSN 583) surfaced at the North Pole, 9 February 1960. On the first winter deployment under the polar ice,* Sargo *sailed more than 6000 miles and surfaced 20 times in the worst imaginable conditions.*

Computer Systems

Although nearly 20 years would pass before the popular press heralded the "age of the micro," NEL had appreciated that advances in solid-state electronics and digital circuitry offered a quantum increase in reliability and computing power. Systems could be built based on a computer that could do the following: take data from radars, sonars, and radios; collate, store, and process the data; and then disseminate the data directly to equipment or to displays for human evaluation. In the early 1960s, NEL was able to demonstrate the feasibility of direct digital control of a large weapons system by using the same digital computer that processed the target data.

During this time, NEL also focused on display technology, that is, determining what information is necessary at each level of decision and how best to present that information (for example, whether to print the data on paper or to display it on a screen). NEL computer engineers worked on fiber-optic displays; large-screen displays; high-speed, solid-state matrix displays; and highly specialized circuitry for rapid reviewing of information. Reliability was a major concern, especially of peripheral devices such as printers and magnetic tape drives.

Command Ship Data System (CSDS)

During the early 1960s, NEL engineers developed a specialized command and control system for the National Emergency Command Post Afloat installed aboard the converted command ship USS *Wright* (CC 2). This system, the Command Ship Data System (CSDS), became operational in 1964 and was later adapted to serve Navy Commanders in Chief in Europe and the Western Sea Frontier.

Fleet Flag Data System (FFDS)/Integrated Flagship Data System (IFDS)

Offshoots of the Command Ship Data System were developed to acquire, process, store, and display large quantities of operational data. The best known of these command and control systems was the Fleet Flag Data System (FFDS), which gave the same capabilities to fleet commanders afloat as the parent system had given to the Navy Commanders-in-Chief. The Integrated Flagship Data System (IFDS), which became operational in 1970, extended the same data-handling capabilities to other flagship units.

IFDS. Operator views geographic display aboard USS Providence *(CG 6).*

Automated Data Systems

NEL's pioneering work in automated data systems, particularly the Naval Tactical Data System (NTDS), led to an increasing number of similar projects during the 1960s. NTDS, by assimilating quantities of diverse information in different formats in realtime and presenting the data as a common output, set the standard for Navy automated data systems. The designers of NTDS, by adopting a "building-block" approach, made it possible to reconfigure the system for specialized applications and to adapt it to accommodate other inputs.

Small Ship Combat Data System (SSCDS)

One early application of the building-block approach was the development between 1964 and 1968 of the Small Ship Combat Data System (SSCDS) to apply the same advantages of high-speed automated tactical data processing to ships smaller than those for which NTDS had been designed.

ASW Ship Command Control System (ASWSCCS)

The success of SSCDS led to a specialized command control system for ASW: the ASW Ship Command Control System (ASWSCCS). Work began on ASWSCCS in 1966 and became operational aboard USS *Wasp* (CVS 18) with the Atlantic Fleet in 1968. The success of ASWSCCS led the Navy to designate NELC lead laboratory for the design and development of the larger ASW Force Command Control System.

Navigation: Omega

The low-frequency Radux navigation effort was superseded in 1957 by a new effort to use VLF radio transmissions from widely separated shore stations. The idea of using VLF for navigation stemmed originally from a proposal by J.A. Pierce of Harvard. Pierce hypothesized that a navigation system could obtain accurate position fixes by measuring the phase of a radio wave and by using a frequency band that is phase-stable and little affected by changes in the ionosphere. At that time, the Navy had several different radio navigation systems, each of which was usable only in certain areas. The principal system, Loran, required 57 stations worldwide and yet only managed to cover 10 percent of the earth's surface. Its accuracy was ±2 nautical miles.

Sponsored by BuShips, NEL set to work on Pierce's idea in 1957, and in 1959, conducted extensive tests between Hawaii and California. NEL was lead laboratory throughout and specifically designed the shore station equipment and the first experimental shipboard receiver. The equipment used precisely timed, continuous-wave VLF (between 10.2 and 13.6 kHz/second) pulses from widely separated land-based sites. Receivers could measure phase differences between the four signals to determine lines of position and then plot these against charts to determine location. The advantage of VLF signals is that they do not vary between night and day or according to weather. In addition, VLF signals penetrate the sea to considerable depths and penetrate the polar ice. Between 1960 and 1968, NEL engineers made the system, now named Omega, operational on aircraft, ships, and submerged submarines. The laboratory procured most of the original prototype equipment and furnished the technical support during installation,

Omega station at Bratland, Norway, 1967.

Omega provided position fixes worldwide to within half a nautical mile during the day and 1 nautical mile at night. The system required just eight stations, and its receiver was comparatively inexpensive and simple to use. The U.S. services, American and foreign commercial shipping, and private aircraft and boats adopted Omega. Today, Omega is available to all nations and all platforms. As a follow-on, NEL/NELC developed the differential Omega system between 1962 and 1979, a coastal navigation system widely used in the Mediterranean and elsewhere.

testing, and operation. The Naval Research Laboratory designed the aircraft receiver and helped NEL with evaluations of the system. NEL prepared the skywave corrections for the western Atlantic, Gulf of Mexico, Caribbean, and West Coast waters off Central America. Scientists in the Netherlands and Britain also provided extensive data. The first four systems were built in Haiku, Hawaii; Forestport, New York; Bratland, Norway; and Trinidad, West Indies. Subsequently, four more stations were added.

Fleet Operational Readiness Accuracy Check Sites (FORACS)

In the 1950s, the Navy had no facilities to calibrate sonars or to determine range and bearing accuracy. The Applied Physics Laboratory at the University of Washington proposed that special facilities be developed for this purpose, and NEL was chosen as lead laboratory and technical director for development. After initial development work at the Applied Physics Laboratory and NEL, construction began in the early 1960s on the first Fleet Operational Readiness Accuracy Check Sites (FORACS) range at San Clemente Island. The FORACS range consisted of three precision-surveyed optical tracking stations on shore, along with various radar, sonar, and optical targets. A central control building containing communications and computer equipment monitored sensor performance data. With the computers at the site, preliminary results could be sent to a ship within 24 hours of the on-range tests.

The first FORACS range became operational in 1965; a second at Nanakuli, Hawaii, followed. Two East Coast ranges were developed at Guantanamo Bay, Cuba, and on Cape Cod, Massachusetts.

Periodic tests of ships' sensors at FORACS ranges led to the discovery of systems errors and shortcomings in documentation that might otherwise have passed unnoticed in the ordinary course of operations.

The usefulness of the FORACS ranges, even now, is in their ability to standardize and repeat tests that had previously been expensive and difficult to arrange. Initially, FORACS addressed the needs of the Fleet's sonars, but the ranges' capabilities were later extended to encompass radar, navigation, and electronic support sensors. Five U.S. sites are presently operational as are two NATO sites. The U.S. sites are located at San Clemente Island, California; Oahu, Hawaii; Fishers Island, New York; Andros Island, Bahamas; and St. Croix, U.S. Virgin Islands. The NATO sites are located on the island of Rennesoy in Norway and on the Greek island of Crete.

Operator collects data from the bridge surface-search radar range/azimuth indicator during FORACS testing.

Laser research. Dr. Erhard Schimitschek (left) and chemist Rick Nehrich (right) stand behind the first laser cavity that produced a visible beam by using a liquid laser material.

Lasers

NEL's work with lasers demonstrated a willingness and an ability to employ emerging technologies to solve field problems. In the early 1960s, a young NEL scientist designed and built the first liquid laser that produced a visible light beam. Born in Czechoslovakia and educated in Germany, NEL's physical chemist, Dr. Erhard Schimitschek, was one of the first scientists to theorize that solutions containing rare-earth chelates (that is, based on very heavy elements) would make suitable lasers. Schimitschek used Europium, Element 66, combined with a ring molecule of benzoylacetonate, to demonstrate a visible beam of coherent radiation, a big step in developing a laser that could be used for communications or surveillance.

NEL used lasers in 1965 in at-sea tests off San Diego that tracked ships during sonar tests. The tests demonstrated that lasers could be used to determine ranges. One example was a jeep-mounted optical detection system for patrolling the perimeters of bases. The system was developed under the Vietnam Laboratory Assistance Program (VLAP) (discussed later). The same laser technology was applied to other systems to mark and optically detect people and vehicles moving along trails and waterways.

During the late 1960s, the emphasis in laser research shifted from extremely high-power lasers to lower power lasers in the blue-green portion of the spectrum that offered greater potential for communications.

Shipboard Communications: Message Processing and Distribution System (MPDS)

In May 1966, as the war in Southeast Asia intensified, Naval Ships Systems Command (NAVSHIPS), in response to an urgent request from the Pacific Fleet for assistance in handling shipboard communications, tasked NEL to design and implement within 1 year a computerized system for handling the internal message traffic aboard USS *Oklahoma City* (CLG 5) (flagship for the Seventh Fleet). For some years, NEL engineers had been addressing the problem as part of a long-term effort (the Naval Ships Advanced Communications Systems project), and they applied findings from that work to the urgent request from the Fleet. Using the NTDS computer and necessary peripheral devices, NEL developed and built the system. Much of the work took place in Battery Ashburn. As in later "rapid prototyping," documentation, maintenance procedures, and training were done simultaneously with development of the system.

The Message Processing and Distribution System (MPDS) was delivered a month ahead of schedule in May 1967. The central MPDS equipment was in the main communications center of the cruiser. Operators manually entered message tapes, and the system then relayed the messages to the appropriate user terminal. The computer memory could store 5200 messages (an impressive number at that time), but microfilming was required for long-term archiving of message traffic. As with many other NEL systems before and since, MPDS relieved communications personnel of much tedious, repetitious work. The MPDS was the first major departure from the precomputer era of manually logging in, distributing, storing, and locating messages. A much more automatic version of MPDS was developed later and installed aboard *Nimitz*-class carriers.

MPDS in Battery Ashburn, 1967. Work on this first automated system for handling shipboard message traffic was completed in less than a year; much of the work took place in Battery Ashburn.

Vietnam Support

Although the Vietnam conflict was primarily a land and air operation, the Navy laboratories played a substantial role in the war. Both NELC and NUWC were involved under the Vietnam Laboratory Assistance Program (VLAP), which DNL established in 1967. Under VLAP, Navy laboratories provided minimally six full-time engineers for the Naval Research and Development Unit–Vietnam.

NELC provided one engineer to serve a 1-year tour of duty as engineer in residence, responsible for navigation, electronics, and other problems that might arise. In addition, NELC engineers made trips to shore or afloat units as the need arose. The engineers were based either in Saigon or Da Nang and spent 3 or 4 days per week helping either the Navy's units in the Mekong River Delta or the Marine Corps north of Saigon. Laboratory representatives sent weekly audio tapes back to Pasadena or San Diego, explaining what they had encountered. The laboratory coordinator referred the problem to the appropriate branch at the laboratory.

Throughout the war, the laboratories solved problems ranging from silencing spark plug noise on small boats to supplying continuous and precise navigational data to help shore bombardment. One task was to develop a variable-intensity polaroid radar filter. Light emitted from radar scopes was too bright for night operations so NELC engineers designed a filter for the river patrol boats. NELC built 200 filters within 2 months of first receiving a request for action. Another quick-reaction project was a navigation improvement system designed to provide continuous, precise navigation data essential to the battleship USS *New Jersey* (BB 62) after it was reactivated for missions in the Tonkin Gulf. In addition, a brass model of *New Jersey* was built at the model range and used in the design of an antenna system. Also, a version of the NEL hand-held sonar, developed to help scuba divers locate small objects, proved useful in Vietnam operations.

Another project affecting operations in Vietnam (although begun at NURDC in 1970) is also noted here: Information on the more common dangerous animals of Southeast Asia was gathered from

Brass model of USS New Jersey *(BB 62) on the turntable of the model range. The model was used in the design of the antenna system for the battleship when it was reactivated for missions in the Tonkin Gulf in 1968.*

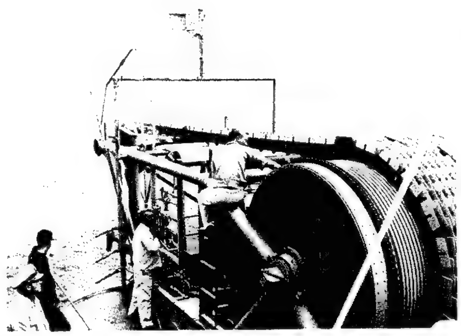
Directional Finder. VHF/DF antenna (mounted on bow) aboard PBR 208 support craft developed under the Vietnam Laboratory Assistance Program.

several sources including underwater demolition teams (UDTs), the Marine Corps, and civilian personnel. NURDC scientists prepared a handbook to provide field personnel with the best information on the safest way to deal with sea snakes, land snakes, and crocodiles. The distributed handbook helped to reduce fears based on misinformation and was of valuable use to field and medical personnel.

In time, VLAP led to the Navy Science Assistance Program (NSAP). NSAP assigns laboratory researchers to operational units for 1-year tours of duty and provides a means of appraising the practical needs and difficulties encountered by the Fleet.

Thermal Mapping of the Ocean

During the early 1960s, NEL developed a thermistor chain to map the thermal structure of the various layers in the ocean. The results obtained by the thermistor chain illustrated the way in which undirected "pure science" supported the military objectives of the Navy's laboratories as a whole. The chain, 900 feet long, was towed in a near vertical position by an NEL research ship. Every 27 feet along the chain, a thermistor bead sensor read the water temperature. This information was transmitted to the research ship, whose instruments recorded the resulting depth, distance and time charts in a line of isotherms. Much of this work took place in the Gulf of California or in the Pacific off San Diego. The data were used to map the ocean acoustically and to support transducer and sonar development. Using the chain, other NEL oceanographers mapped segments of the Bering Sea.

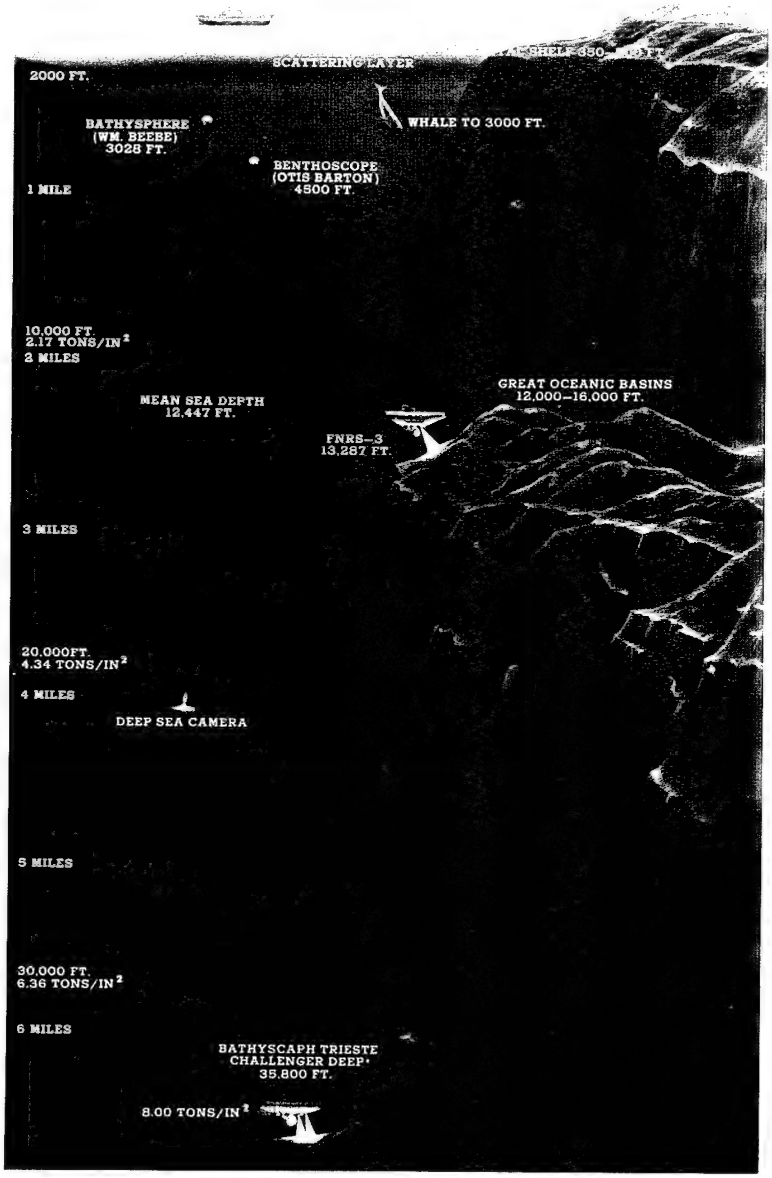


Thermistor chain developed to map the thermal structure of the ocean.

Deep Submergence: *Trieste*

On 23 January 1960, Lieutenant Don Walsh of NEL and Auguste Picard's son, Jacques, took the bathyscaph *Trieste* into the Challenger Deep Trench in the Pacific Ocean, 200 miles southwest of Guam. Before returning after 9 hours, they took *Trieste* to a world-record 35,800 feet, nearly 7 miles beneath the sea. The record still stands. Picard ended his contract with ONR shortly afterwards, but Walsh and his Navy colleague, Lieutenant L. A. Shumaker, continued to pilot *Trieste* in a series of NEL-directed expeditions in 1961 and 1962. Equipped with plankton samplers, a salinity monitor, temperature probes, and water sampling bottles, *Trieste* usually made one dive a week, taking the winter months off for refitting and overhauling.

Trieste's last dives, if not the most celebrated, were certainly the most poignant. On 10 April 1963, the new nuclear submarine USS *Thresher* (SSN 593) was lost 270 miles east of Boston, Massachusetts. The Navy launched an immediate rescue effort, but rescuers soon learned that there would be no survivors. In the depths at which *Thresher* had been lost (8400 feet), the submarine would have imploded from the pressure.



Trieste began diving for *Thresher* in June 1963. Under Lieutenant J. Brad Mooney, the officer-in-charge (later Chief of Naval Research), and Kenneth Mackenzie, NEL scientist-in-charge of the Deep Submergence Program, *Trieste* set to work at depths of over 8000 feet. *Trieste* proved able to navigate on the Atlantic Ocean bottom and surveyed the bottom systematically. *Trieste*'s crew located pieces of *Thresher*, which they photographed. After a brief overhaul, *Trieste* returned in August and found major pieces of wreckage and used a newly fitted mechanical arm to retrieve a section of piping. The *Trieste* operations led to determining what caused the loss of the submarine and what design changes needed to be made to avoid future failures.

On 23 January 1960, Trieste *descended into the Challenger Deep to a record 35,800 feet.*

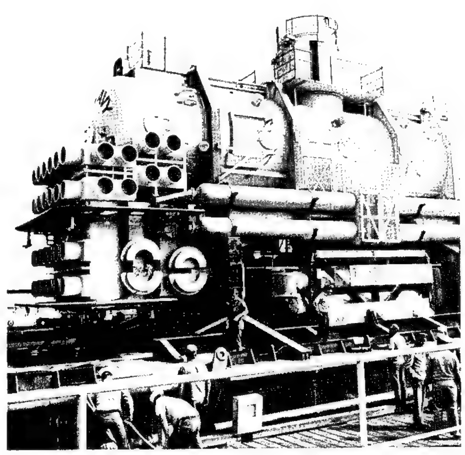
Undersea Habitat: Sealab II

Following the loss of *Thresher*, the Navy established the Deep Submergence Systems Project (DSSP) to develop techniques and equipment to improve capabilities in the deep ocean environment. Both NEL and NOTS Pasadena played important roles in several DSSP programs. In 1965, as part of its Man-in-the-Sea program, DSSP conducted the Sealab II experiment at a site off the coast of La Jolla, California. The Sealab II experiment consisted of three 10-man teams living and working in the Sealab undersea habitat at a depth of 205 feet. Each team would spend 15 days underwater. The project was conducted for a total of 45 days—from 28 August to 14 October 1965.

An NEL diver and photographer, Bill Bunton, participated in Sealab II, as did the original Project Mercury astronaut, Scott Carpenter. Sealab II's living compartment included a laboratory, galley, and bunkroom. In their self-contained environment, aquanauts breathed a mixture of 80-percent helium, 16-percent oxygen, and 4-percent nitrogen. The project had three phases: human performance measurement, oceanography, and salvage of a Navy jet that had been sunk for the experiment. Sealab II conducted several diving and decompression experiments, including total gas saturation dives, deep excursion dives without decompression, and exploration. The aquanauts ate fish, crabs, and even raw plankton, as part of their effort to demonstrate that aquanauts could function at such depths. One of the highlights of Sealab II was a conversation between Scott Carpenter, 200 feet underwater, and astronaut Gordon Cooper, who was circling the earth in a capsule 200 miles in space.

NOTS Pasadena provided the staging vessel that the Long Beach Naval Shipyard modified to NOTS specifications. And NOTS Pasadena installed and maintained all the special equipment, including the decompression chamber and the personnel transport capsule. While Sealab II experiments were proceeding, NOTS personnel provided all the surface support, which included operating the staging vessel and handling numerous small boats.

NOTS Pasadena also provided a marine mammal for tests. The second team of aquanauts conducted tests with Tuffy, a bottlenose dolphin, trained to respond to sound signals, to determine whether such an animal could be useful to persons in the sea. Initially, Tuffy did not respond as expected, probably because of the new surroundings and noise from the surface support ship. However, Tuffy soon began making several dives from the surface to 205 feet and delivered mail, tools, and messages. In another test, Tuffy carried a guideline from the habitat to an aquanaut who was signalling that he was in need of assistance. The tests demonstrated that trained dolphins could work untethered in the open sea with great reliability.



Sealab II undersea habitat.

A Sealab II diver determining the orientation of a gorgonian coral.

Marine Mammal Program

The Navy's Marine Mammal Program had its origin in the acquisition, in 1960, of a Pacific white-sided dolphin for hydrodynamic studies. Scientists at NOTS China Lake and Pasadena had heard accounts of the hydrodynamic efficiency of dolphins (sometimes called porpoises to distinguish the dolphin-mammal from the dolphin-fish). Since NOTS was in the business of designing and developing torpedoes, it seemed reasonable to find out whether dolphins did, in fact, have special characteristics that might be applied to the design of underwater missiles.

Work with the white-sided dolphin, named Notty, revealed no unusual physiological or hydrodynamic capabilities, but it was suspected that conditions in the long testing tank in which she swam might have affected her performance. NOTS scientists and engineers looked for an appropriate site at which to establish a small research facility to continue their investigation of dolphins.

They found such a site at Point Mugu, California, where the Pacific Missile Range and Naval Missile Center were located. By coincidence, a group in the Life Sciences Department of the Naval Missile Center was also proposing to undertake studies of marine life, including dolphins. Mugu Lagoon, the last such body of protected water on the Southern California coast, was seen as a great asset for such work.

As a result of these mutual interests, and with encouragement from the Office of Naval Research, a modest facility for research and exploratory development gradually evolved on a sand spit between the lagoon and the ocean at Point Mugu. The program got underway in 1963. Primary interest was in marine mammals—the study of their specially developed senses and systems, such as sonar and deep-diving physiology—and also how marine mammals might be used to perform useful tasks.

Scientists from universities nationwide visited the facility to observe the pioneering work of Sam Ridgway (the first veterinarian to work full-time with dolphins) and to learn how marine mammals have adapted to life in the sea. Many people had thought it impossible to work with a dolphin free in the open sea—where it has access to abundant food, is free to join herds of its own species, and is free to roam the ocean. Yet trained dolphins such as Tuffy continued to demonstrate with Sealab and other projects, a motivation to return and a capability to perform with a high degree of precision and reliability. Diving at 600 or 1,000 feet in the ocean is a dangerous undertaking for humans, but for dolphins this is a natural act of daily life, almost entirely without danger.

In 1967, the Point Mugu facility and its personnel, both of NOTS and the Naval Missile Center, were placed under NUWC, with headquarters in San Diego. Following the opening of the Hawaii laboratory on Kaneohe Bay, some personnel and animals at Point Mugu transferred to Hawaii, and later the rest of the Point Mugu operation moved to San Diego to continue research and development in marine biosciences.

Remotely Operated Vehicles (ROVs)

During the 1960s, NOTS Pasadena began to develop a new mission. As part of its work at the Navy's San Clemente Island test range as well as its own waterfront activities at Long Beach, NOTS carried out several basic tasks connected with testing underwater ordnance. When testing torpedoes, NOTS engineers tried whenever possible to recover the torpedo and its exercise head, that is, the data-recording gear that replaced the warhead in a weapon under development. Having the exercise head allowed researchers to assess performance and to locate faults.

Although the test torpedoes were designed to float to the surface at the end of their run, occasionally units sank to the seafloor. When the torpedoes sank in shallow water (to depths of 200 feet), Navy divers were able to recover them. However, as torpedoes and other weapons were ranged in deeper and deeper waters, other recovery means were required.

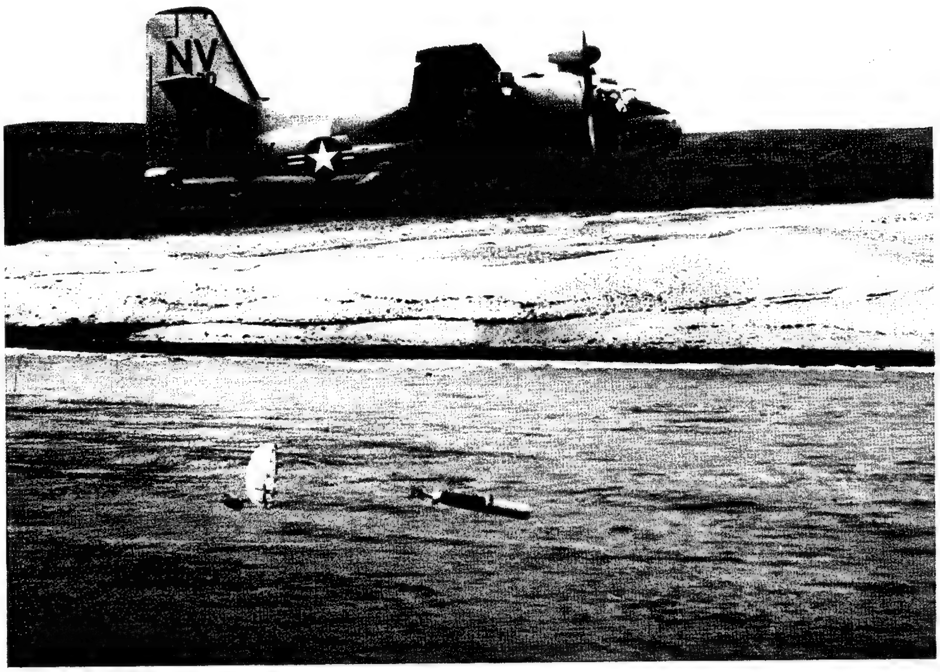
During the early 1960s, NOTS Pasadena engineers developed a remotely operated vehicle known as the Cable-Controlled Underwater Recovery Vehicle (CURV). This vehicle was equipped with a sonar, a television, and a claw designed to recover torpedoes at depths to 2000 feet. CURV was successfully demonstrated in 1965.

CURV was put to further use in early 1966. In January 1966, an Air Force B-52 collided with a KC-135 tanker off Palomares, Spain. The bomber was carrying four hydrogen bombs. Three of the unarmed bombs fell into the Spanish countryside, where they were quickly recovered. The fourth dropped into the Mediterranean. Local fishermen gave the Navy a good idea of the bomb's approximate location, and a small armada of search and recovery vessels was assembled. The manned submersible *Alvin*, operated by the Woods Hole Oceanographic Institute, succeeded in locating the bomb but had no way of recovering it. In fact, *Alvin* got tangled in the parachute shroud of the bomb and was almost lost.

CURV was the only system that could both search for and recover objects. A new cable was quickly spliced onto CURV to extend its range. The vehicle and its crew, headed by Howard Talkington, were airlifted to Spain. On its third dive, CURV located the bomb, grabbed the lines of its parachute, and, early on the morning of 7 April, hauled the lost H-bomb to the surface.

Hydrogen bomb rests on deck of USS Petrel *(ASR 14) after being recovered during CURV operation.*

Following CURV's success in the Mediterranean, NOTS Pasadena began planning a CURV with a deeper operational capability. During the planning, NOTS found that CURV I was not reliable enough for its range operations. Two CURV systems were developed concurrently: CURV II to operate more reliably during range operations and CURV III to respond to national emergencies. CURV II retained most of the features of CURV I but was modified to replace inadequate components. CURV III used the best of the original CURV concept but was otherwise a new system. CURV III was designed with an initial depth capability of 7000 feet, which was later increased to 10,000 feet.



Mk 46 Mod 0 launched by an ASW aircraft during sea operations test program. The Mk 46 can also be launched by ASROC, helicopters, and surface ship tubes.

Torpedo Mk 46

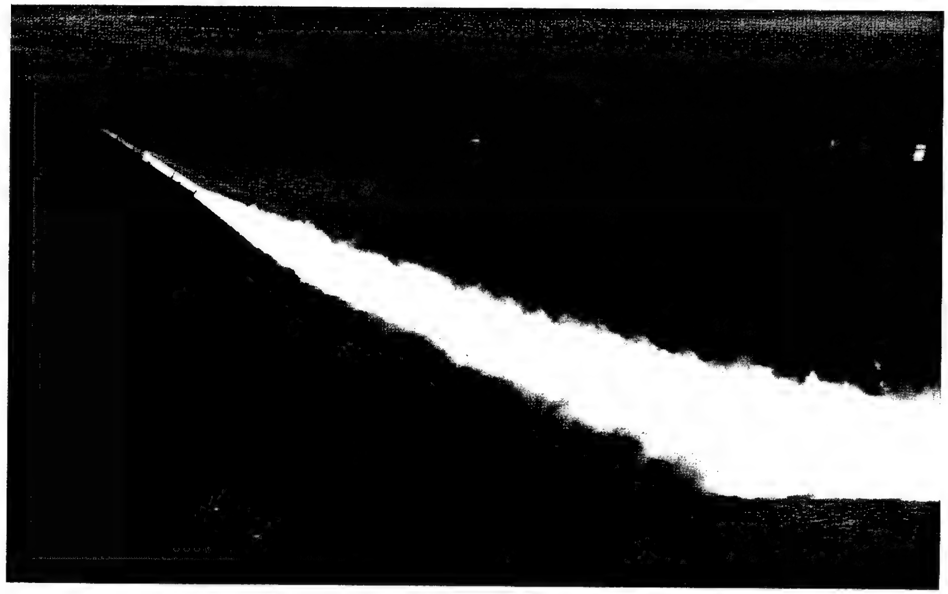
When the Torpedo Mk 44 reached the Fleet in 1958, R&D on a more capable successor had already begun at NOTS Pasadena. NOTS would not only design and develop the new torpedo but would oversee its manufacture, help introduce it to the Fleet, and maintain and upgrade it once in service. NOTS engineers also addressed the design of the torpedo's acoustic homing system. The torpedo could home-in on its target with an active-passive acoustic head and either follow the target's radiated noise or, if the target were silent, search for it with active sonar. Thus, the guidance system functioned in two modes, termed "passive/active circle," or "active snake mode," to detect and then localize enemy submarines.

Although torpedo development might easily be thought of as primarily applied engineering, the development of lightweight torpedoes drew heavily upon relevant fundamental research. Indeed, in the mid-1960s, about 10 percent of the annual budget of NOTS Pasadena went toward basic research. The most significant research and development that went into the Mk 46 was the REVEL guidance system. Until the REVEL system went into the Mk 46, torpedo guidance had not changed appreciably since World War II. The Mk 46 continues today as the Navy's standard lightweight torpedo.

In a related effort to this torpedo work, the chemistry group at NOTS Pasadena did considerable research on how polymers might be used to reduce hydrodynamic drag. Even very small concentrations of these synthetic coatings and natural substances could reduce turbulence and thus extend the range and speed of torpedoes. Commercial applications to internal pipe-flow have since been implemented in fire-fighting systems and in long-distance oil pipelines.

Submarine Rocket (SUBROC)

Developed as an outgrowth of earlier work to determine the feasibility of systems such as ASROC, the submarine rocket (SUBROC) system was essentially an underwater guided missile that could be fired from above or below the surface. The Naval Ordnance Laboratory at White Oak, Maryland, developed the project and Goodyear Aerospace Corporation was the prime contractor. NOTS Pasadena was tasked with carrying out the underwater firings of SUBROC at San Clemente Island. The SUBROC system was designed to detect a submarine at long range, compute its course and speed, and fire a missile. In 1963, NOTS Pasadena accomplished the first successful firing of a SUBROC flight test vehicle from a submarine off San Clemente Island.



SUBROC. Underwater firing of SUBROC off San Clemente Island.

ASW Fire Control Systems (FCSs)

The Fire Control Group (FCG) Mk 111 was developed by NOTS Pasadena to compute and control the placement of ASROC-delivered payloads. First-production FCG Mk 111 sets entered the Fleet in 1960.

NOTS developed the FCG Mk 111 to control and fire all ASROC missile configurations at ranges exceeding an order of magnitude over previous ASW weapons. The FCG Mk 111 was significant in that it introduced digital equipment into Navy vessels and implemented the first successful math model of a complex weapon system. A large-screen optical plotter was also developed to display the tactical geometry of the ASW attack scenario. The development of the FCG Mk 111 allowed Navy vessels to deliver ASW weapons at extended ranges with great accuracy and minimized the exposure of the firing vessel to counterattack.

Between 1959 and 1961, NOTS Pasadena conducted an R&D development program to include other ASW weapons in addition to ASROC in ASW fire control equipment. By modifying the FCG Mk111 math model, NOTS developed a more versatile ASW fire control system (FCS), the FCS Mk 114.

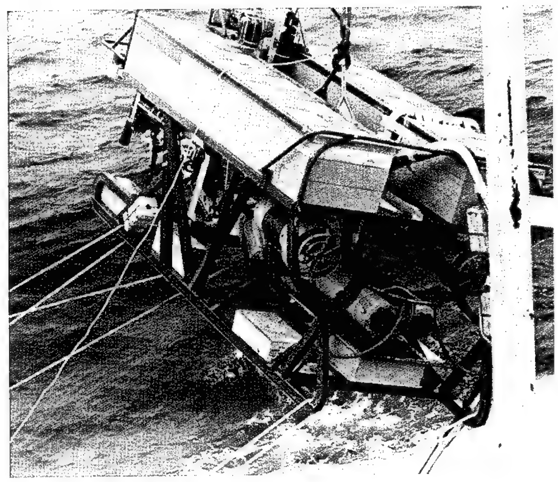
The FCS Mk 114 allowed Navy vessels to deliver a variety of ASW weapons more accurately. First-production FCS Mk 114 sets entered the Fleet in 1962. The tactical versatility of the FCS Mk 114 provided the capability to effectively meet the nuclear submarine threat in both stand-off and search-and-destroy ASW missions.

In the late 1960s, conceptual development work was performed that led to production, in the 1970s, of the Mk 116 underwater fire control system. This system became the first surface ASW digital fire control system to communicate directly to a digital launcher. The entire computer programming for the Mk 116 Mod 1 was performed in-house. Using the modular programming concept, the computer program proved extremely reliable and adaptable to changes. It integrated the standard equipment of computer (UYK-7) and display console (UYA-4) to ASW use and thus helped to standardize shipboard equipment.

Underwater Missile-Launch and Propulsion Technology

Over the years, NOTS/NUWC scientists and engineers participated in developing the concepts and technology for underwater missile launch. Every underwater-launched missile in use by the U.S. Navy continues to undergo full-scale development testing at the San Clemente Island test range prior to certification for use onboard U.S. submarines.

Also, NOTS engineers at the Morris Dam facility near Pasadena led the way in the significant development of new torpedo propulsion concepts. The requirements for high speed through the water, silent running, and maximum range necessitated several solutions. Experiments on new chemical fuels, high-energy batteries, prime movers, and thrust-producing mechanisms all contributed to further advances in the Navy's torpedo program.



Introduction

NUWC had been renamed the Naval Undersea Research and Development Center (NURDC) in 1969 and, by 1970, NURDC had approximately 1400 full-time employees and 370 military personnel. Most of the staff referred to the laboratory as the Naval Undersea Center (NUC), and in 1972, the name was officially changed.

In May 1974, NUC Pasadena was disestablished and its functions and personnel were transferred to NUC headquarters in San Diego. Also in May 1974, NUC dedicated its first new building, the Undersea Weapons Laboratory, a poured-concrete, low-maintenance structure on the waterfront. In September 1976, the building was renamed the William McLean Laboratory in honor of Dr. McLean, the first Technical Director of NUC, who died in 1975, a year after retiring.

Beginning in 1972, NUC updated a sound beacon concept by developing a torpedo-tube-launched, self-propelled decoy. In 1975, NUC was designated lead laboratory for the new Advanced Lightweight Torpedo, later to be designated the Mk 50 torpedo. The laboratory continued to support and enhance the Mk 46 torpedo, which today remains in the Fleet.

Also in the 1970s, the Hawaii laboratory pursued research in marine biosystems and manned and unmanned submersibles and developed the Navy's first Small-Waterplane-Area Twin Hull (SWATH) ship. Beginning in 1974, the Hawaii laboratory performed environmental assessments for several Navy facilities worldwide.

Responsibility for the new field of undersea surveillance was assigned to NUC. Work in undersea surveillance included support of the shore terminals and signal-processing software for the Sound Surveillance Underwater System (SOSUS) and development of the Surveillance Towed Array Sensor System (SURTASS).

As for NELC, by 1970, its employees numbered approximately 1370 civilians and 133 military personnel. In July 1970, a Command Control and Communications Programs Department was established to manage major long-term programs, direct associated system development projects, and establish objectives in supporting technologies. Four major departments were also formed upon which the Programs Department could draw for specialized technical work. These included two technology departments—Electromagnetics Technology and Information Technology—and an Engineering Sciences Department and a Computer Sciences Department. An Administrative and Technical Support Department was also created to provide a coherent internal structure for all activities outside the strictly RDT&E effort.

Over the next several years, NELC pioneered advances in solid-state electronics and digital circuitry, lasers, under-ice sonars, radio physics, ocean research, satellite communications, and ionospheric forecasting.

The year 1977 brought the merger that formed NOSC. NELC and NUC were consolidated as NOSC to provide a broad-spectrum systems capability and to facilitate integration of major mission areas.

New Facilities

McLean Laboratory, Building 1, Bayside

In November 1973, construction was completed on NUC's first new building. Dedicated in May 1974 as the Undersea Weapons Laboratory, it was renamed the William McLean Laboratory in September 1976. Located near the waterfront on San Diego Bay, the facility is a five-level, 150,000-square-foot laboratory/shop/office complex for approximately 500 people. The facility continues to support the Center's major roles in integrated ASW and ocean engineering. A major capability within the McLean Laboratory is the performance of hardware-in-the-loop simulation, including both digital and hybrid simulation. The laboratory allows the development and exercise of detailed acoustic models of targets, countermeasures, and operating environments for use in undersea weapon simulations. Building 1 also houses laboratories for ASW data fusion, the development of future guidance and control concepts, materials physics for torpedo electronics applications, and signal processing for ASW tactical surveillance arrays. Vault spaces provide a controlled environment for much of this work. Ocean engineering offices are also located here, and the facility is presently the focus for the broadband local area network that interconnects many host computers.

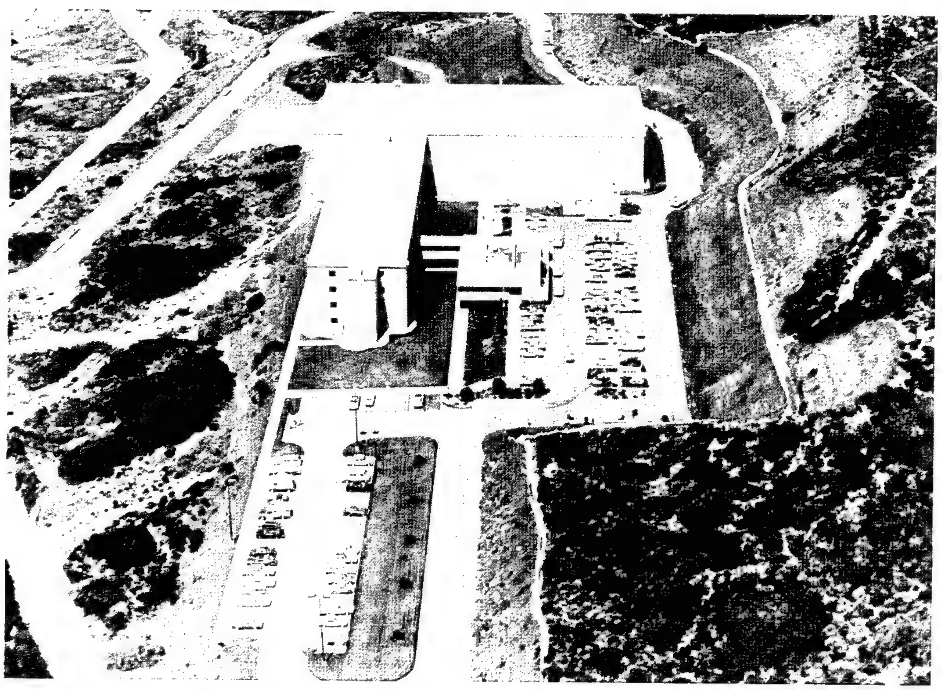
William McLean Laboratory, Building 1, Bayside.

C^3 SITE, Building 600, Seaside

To meet the Navy's need for development and integration of emerging tactical command, control, communications, and intelligence systems, NELC completed, in 1976, the Command, Control, and Communication Systems Integration Test and Evaluation (C^3 SITE) facility, also known as Building 600, Seaside. Originally called the Electronics Development and Test Laboratory (EDATL), this working facility makes possible, in one secure and electromagnetically shielded location, the solution of problems in a laboratory setting that otherwise would require costly and time-consuming shipboard evaluation. The C^3 SITE consists of three contiguous buildings with a total of 55,000 square feet of shielded space. Built below the ridge on the west side of Point Loma, the facility provides ready communications access to the at-sea exercise/operating areas immediately to the west.

NURDC/NUC Name Change

Captain Charles Bishop, former Commanding Officer of NURDC and later Assistant Director of Engineer Operations at MPL, recalls these events: "When I first came onboard, the name of the Naval Undersea Warfare Center had just been changed to the Naval Undersea Research and Development Center, NURDC. Well, I couldn't stand it. I told people, 'I am not going to be the head of a bunch of nerds.' So it was called the Naval Undersea Center. We kept getting mail from Washington addressed to NURDC, and I replied from the Naval Undersea Center. That went on for over a year. They finally said, 'Well, hell ...' and they got it changed."



C^3 SITE, Building 600, Seaside.

San Diego: Toward Merger

The technical departments of NELC and NUC shared work in fields as varied as signal processing, display technology, undersea optics, and many aspects of microprocessors. Beginning in 1973, representatives from the two centers met regularly to explore areas in which consolidations could reduce overhead. As the Vietnam War wound down, the defense budget, including its R&D portions, received careful scrutiny. Consequently, activities such as NELC and NUC were required to reduce costs.

Following the 1973 DoD Shore Establishment Realignment program, NUC Pasadena was disestablished on 3 May 1974. Special technical facilities, offices, and shops were transferred to San Diego along with direct functions and personnel. This transfer resulted from an overall reduction in the Naval Shore Establishment.

Mission Areas

In 1975, NELC was chartered to be the Navy's principal RDT&E center for "electronics technology and command control and communications concepts and systems." In reality, NELC shared these missions to a considerable extent with the Naval Research Laboratory. To some in the Navy and Congress, this overlap suggested a wasteful duplication of effort. One major difference between NELC and NRL, however, was the greater emphasis at NRL on basic research and the greater emphasis at NELC on direct fleet support. The NELC emphasis was on short-term projects that were directly relevant to identified Navy needs and that would quickly benefit the Fleet. Basic research and development continued in areas most closely linked with the Center's major missions, namely electronic materials and electromagnetic propagation.

In 1972, NUC's role in undersea surveillance was expanded and NUC was chartered to be the Navy's principal RDT&E center for undersea surveillance, ocean technology, and advanced undersea weapons systems.

Evaluating the Laboratories

The major Point Loma laboratories, NELC, NUC, and the Navy Personnel Research and Development Center (NPRDC), received a high-level evaluation in 1975 by a task group appointed by CNM and the Assistant Secretary of the Navy for R&D. Mr. M. Goland, vice-chairman of the Naval Research Advisory Committee (NRAC), chaired a panel of five others, including representatives of ONR, NRL, and the major systems commands. The panel visited the three laboratories over a 4-month period. The Goland Report concluded that NELC's facilities were preventing it from fulfilling its mission responsibilities. Persistent hiring and promotion freezes were keeping the Center from attracting and retaining necessary personnel. The Goland Report estimated that NELC was approximately 100 professionals below strength if it were to fulfill its lead laboratory mission for command control and communications.

In late 1975, another panel, the "Lab X Task Group," studied the problem of mission overlap and high overhead. This panel proposed creating a full-spectrum laboratory, meaning that the laboratory would support work in every DoD funding category: basic research, exploratory development, fleet support, and in-service engineering. As originally proposed, "Lab X" would have consolidated virtually all NELC departments,

apart from human factors engineering, and would have taken several divisions from NRL: electronic warfare, information sciences, radar, and space systems. The new Point Loma laboratory would be supported by the administrative infrastructure of both NELC and NUC. But the "Lab X" proposal involved too drastic a realignment of laboratories, and on further investigation, the Navy found that many of the proposed elements were already present on Point Loma.

In January 1976, H. Tyler Marcy, Assistant Secretary of the Navy for R&D, directed Captain Robert Gavazzi, Commanding Officer of NELC, to submit a plan for the consolidation of NELC and NUC. A panel, headed by Captain Gavazzi, spent a year examining the possible merger and reported in favor of doing so. Managers of both NELC and NUC agreed that merger would be desirable.

Merging NELC and NUC

With the groundwork laid, the Navy was ready to merge the two laboratories. Unlike prior mergers and realignments, merging NELC and NUC would not mean moving facilities or families, always an expensive process. Nor would there be Congressional opposition (as from Pasadena congressmen), since no facilities would close. No land needed to be purchased nor environmental impact studies prepared.

The big problem in creating the new laboratory was how to integrate personnel from two very different organizations. To ease the transition, the merger plan established six directorates: one for support and five in the technical areas of marine sciences and technology, weapon systems, ocean surveillance, command control and communications, and engineering and computer sciences. Each directorate comprised several existing departments, some NELC, some NUC. To minimize disruption at the project level, the structure of divisions and branches remained intact for the immediate future.

The managers who were assigned to smooth the merger had to define the mission of the entire center broadly enough to include all the work areas of the two existing centers, but they also had to distinguish the consolidated thrust from other laboratories and still relate it to primary U.S. Navy missions. The designated name of the consolidated laboratory became the Naval Ocean Systems Center. Various issues were time-consuming and delicate. Personnel had to be reassigned; some people's responsibilities increased, other's diminished. The consolidation had four purposes:

- Produce broad-spectrum systems capability.
- Facilitate integration of intelligence, ocean surveillance, C^3, and undersea weapons in support of the Navy's Sea Control mission.
- Combine research and technology programs to provide increased flexibility and larger blocks of funds for broader and in-depth investigation.
- Provide savings realized by combining support functions and through joint facilities usage.

Naval Ocean Systems Center (NOSC)

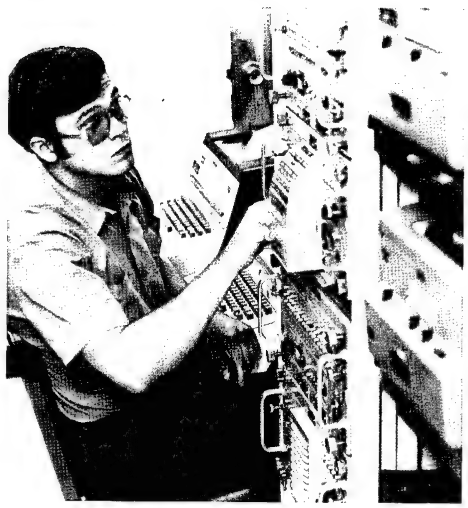
On 1 March 1977, NELC and NUC were consolidated as the Naval Ocean Systems Center (NOSC). NOSC's mission was to be the principal Navy RDT&E center for command control, communications, ocean surveillance, surface- and air-launched undersea weapon systems, and supporting technologies. NOSC was chartered to lead the Navy's R&D thrusts in the following areas: command, control, and communications; ocean surveillance; integration of multiplatform combat systems; deep-ocean engineering; surface ship ASW fire control; lightweight torpedoes; and environmental studies as they bore on ocean surveillance, communications, and command and control. The Technical Director of NUC, Dr. Howard Blood, became the Technical Director of NOSC. The Commander of NELC, Captain Gavazzi, took over as Commanding Officer of NOSC.

New Systems and Research

Fleet Satellite Communications

By the late 1970s, the Navy had communications systems that operated in the UHF, SHF, and EHF areas, and NELC played a critical part in each. Today, for general communications, the Navy relies on UHF fleet satellite communications systems (FLTSATCOM), which the Department of Defense approved as a development concept in 1971. Interim-use satellites were launched in 1976 and used until other FLTSATCOM satellites could be launched later in the decade. The FLTSATCOM system introduced, on a broad scale, the transmission of naval communications via satellite relay and the control of this transmission through automation. FLTSATCOM consists of several subsystems. NELC developed software for all FLTSATCOM Information Exchange Systems (IXSs) and designed and developed secure-voice interfaces. The secure-voice interfaces were developed to serve as a switchboard on which the operator could control secure-voice communications on three independent satellite channels.

Additionally, NELC experts in SHF radio designed the shipboard antennas and the control systems used in the terminals for the shipboard SHF Defense Satellite Communication System. The antennas enabled ships to track satellites during the roughest sea conditions and at the highest latitudes (an important advance, since most satellites orbit near the equator).



Verdin/ISABPS. ISABPS provides on-line multichannel access to the Verdin transmitting system.

Integrated Submarine Automated Broadcast Processing System (ISABPS)

Early in 1973 it was recognized that two major systems, the Submarine Satellite Information Exchange System (SSIXS) and Verdin, being developed for fixed-transmitter, submarine broadcast communications, would not realize their full potential when interfaced via the manual torn-tape method. (Tape would have to be torn off a SSIXS receiver and manually fed into the Verdin transmitters.) NELC initiated a program, the Integrated Submarine Automated Broadcast Processing System (ISABPS), to serve as a redundant, computerized system that would handle multichannel and multiple-rate broadcasts as well as encrypted and special intelligence traffic. ISABPS was designed to receive and verify SSIXS message traffic; prioritize, store, and forward messages; and schedule broadcasts for fixed VLF/LF sites. ISABPS was installed at seven shore VLF/LF broadcast transmitter sites to provide global submarine broadcast coverage.

The Verdin/ISABPS program became one of the largest of its kind accepted by NELC/NOSC and had the unique characteristic of being the first program for which NELC/NOSC was assigned the role of life-cycle support activity.

Integrated Refractive Effects Prediction System (IREPS)

Since the 1950s, NEL/NELC made significant advances in understanding, modeling, and predicting atmospheric effects on radio propagation. In 1973, a fleet-wide conference on the problems of refractivity was held in San Diego. One of the recommendations from this conference was the development of a shipboard assessment capability. NELC was tasked to do this and developed the Integrated Refractive Effects Prediction System (IREPS). With this system, operational commanders were able, for the first time, to properly assess and exploit the serious effects atmospheric refractivity has on sensor and weapon systems performance. IREPS acquired, converted, and interpreted refractivity data from

the lower atmosphere and displayed their effects on specific sensor and weapon systems in near realtime. Refractivity assessment techniques developed prior to IREPS were either too complex or too cumbersome for tactical military applications.

IREPS was first tested aboard USS *Enterprise* (CVN 65) in 1976. Based on its success, the Fleet requested an immediate interim operational capability. NELC/NOSC responded by developing an interim IREPS, which was based on a commercially available programmable desktop calculator. Since the first installation aboard USS *Ranger* (CV 61) in 1978, IREPS has been used operationally on all deployed aircraft carriers, on selected other ships, and at numerous shore installations.

IREPS aboard USS Constellation *(CV 64).*

Inverse Synthetic Aperture Radar (ISAR)

In the mid-1970s, NELC took up the problem of radar imaging of ships. The advantages of two-dimensional target images over simple blips on a screen are important to many Navy missions in which radar is involved, notably target identification, weapons targeting, and damage assessment. The NELC approach to such imaging was to take advantage of, rather than to correct for, the pitch, roll, and yaw of the ship target. The concept is the inverse of Synthetic Aperture Radar (SAR) in that needed view-angle rotation is

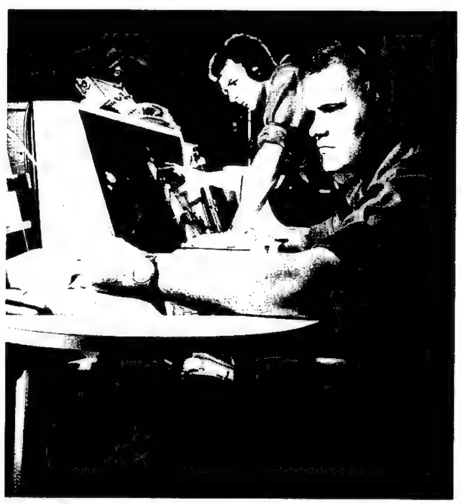
provided by the target instead of the radar platform—thus the name Inverse Synthetic Aperture Radar (ISAR). NELC obtained funding to test the ISAR concept against ship and air targets from a fixed shore site off Point Loma. In 1976, NELC succeeded in collecting the first images of ships. Later, NELC/NOSC demonstrated the feasibility of imaging air targets. The Navy's AN/APS-116 airborne antisubmarine warfare radar was then adapted for ISAR ship imaging by NRL under Project Profile. NELC had previously developed the pulse compression design to obtain high resolution in the AN/APS-116.

Warfare Simulation, Evaluation, and Analysis

In the early 1960s, NOSC's predecessors designed and implemented the Naval Electronic Warfare Simulator (NEWS) for the Naval War College. This analog system enacted platform movements on a large screen and was replaced in the early 1970s by a digital system, the Warfare Analysis and Review System (WARS). In the early 1970s, NELC personnel designed and implemented the Tactical Warfare Analysis and Evaluation System (TWAES), a completely interactive realtime system that could be used as a command and control system for Marine Corps field exercises. Later called the Tactical Warfare Simulation, Evaluation, and Analysis System (TWSEAS), it could also be used as a stand-alone simulation system for Marine Corps C^3 system evaluation or training.

Upgraded and now known as the Marine air-ground task force Tactical Warfare Simulation System (MTWS), the computer-assisted war-gaming system simulates primary aspects of Marine Corps tactical operations, including air, ground, and amphibious operations. As a hardware/software system, MTWS provides realistic combat situations that stimulate a commander and the staff to perform normal command and control decision-making in a war game. NELC developed the original system in a rapid prototyping effort. Work began in 1971, and a limited operational system was functioning by 1973. The USMC took delivery of the first TWSEAS in 1978. At present, there are three MTWS sites: Fleet Marine Force Atlantic, Camp Lejeune, NC; Fleet Marine Force Pacific, Camp Pendleton, CA; and Marine Corps Development and Education Command, Quantico, VA.

The Warfare Environment Simulator (WES), designed and developed by NELC, performed the same functions for the Navy. WES was used by numerous Naval commands as a tool to assess C^3 systems, hypothetical strategies, tactics, weapon systems performance, and effectiveness of organizational structures. WES was a forerunner to the Interim Battle Group Tactical Trainer (IBGTT), which later dropped the "interim" from its name and added the new capabilities of the Research, Evaluation, and Systems Analysis (RESA) system.



TWSEAS. A completely interactive realtime system, TWSEAS could be used as a C^2 system for field exercises, as well as a stand-alone simulation system for USMC C^3 system evaluation or training.

CURV III

On 7 March 1970, NASA launched a scientific payload to study the sun during a total eclipse. The payload, containing irreplaceable data films, was thought to be lost at sea when its recovery system malfunctioned.

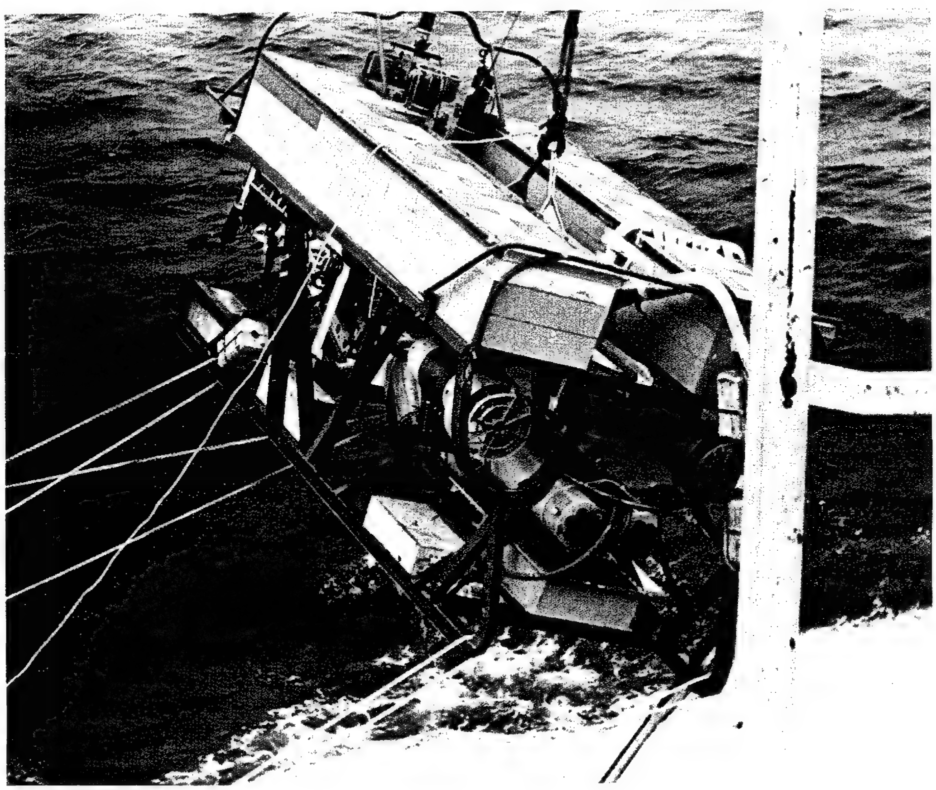
NURDC's CURV III was transported by C-141 aircraft from San Diego to Norfolk and placed aboard USS *Opportune* (ARS 41). Shallow test dives were conducted and operational and logistic plans were made. On 22 March, CURV III completed its search of the ocean floor 75 miles off the Virginia coast and successfully retrieved the payload from a depth of 5,800 feet.

The retrieved payload and its scientific data films were returned to NRL. Many of the films were processed successfully, and the results made a major contribution to understanding the solar corona and chromosphere.

In 1973, CURV played a vital role in a dramatic rescue of the Canadian submersible, *Pisces III*, whose two-man crew was trapped on the bottom of the Irish Sea at a depth of 1,375 feet. CURV III was flown to the scene, launched in heavy seas, and maneuvered into position to attach a recovery line. The recovery was made after *Pisces III* had been stranded for 3 days and as the air supply was nearly exhausted. Both men inside were safely rescued.

In 1976, CURV III assisted in the recovery of an F-14 lost in the North Sea. The aircraft rolled off the deck of USS *John F. Kennedy* (CV 67) and sank in more than 1,890 feet of water. Recovery operations were initiated because of concern that the Soviet Union would attempt to recover the F-14. Despite foul weather, the aircraft was recovered within 2 months.

CURV III. Launching CURV III during Pisces III *rescue operation.*



Divers assist rescued pilots from Pisces III.

Remote Unmanned Work System (RUWS)

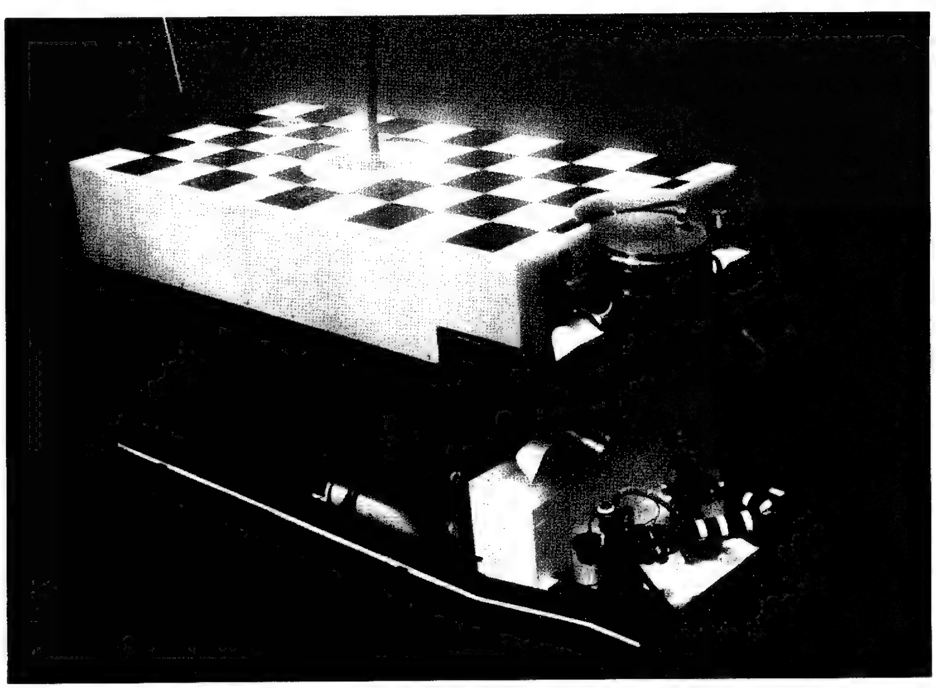
A key project at the Hawaii laboratory during the 1970s was a remote-controlled submersible system called the Remote Unmanned Work System (RUWS). A predecessor of the Advanced Tethered Vehicle (ATV) discussed in the next section, the RUWS project ran from 1974 to 1980. Similar to CURV in type, the vehicle was equipped with a 35-mm still camera, underwater light, and a pair of hydraulic manipulators designed to perform a variety of tasks. RUWS was a focal project under the Deep Ocean Technology program. The objective was to select missions for the development and demonstration of advanced technology that would then be applied to a variety of deep ocean programs. The prime missions selected for the RUWS technology program were recovery, repair, implantment, survey, documentation, and oceanographic data gathering. The objective was to provide a testbed whereby work capability could eventually be extended to 20,000 feet, which would thus provide access to 98 percent of the ocean floor.

RUWS was a pioneering effort that required advances in cable, connector, work systems, and telemetry technology. Developing a cable to take RUWS to great depths was the project's main stumbling block. RUWS became the first deep tethered vehicle to use a single electromechanical support cable and pioneered the use of Kevlar® as a strengthen member for such application. Kevlar has all the properties and the strength of steel and only one-seventh the weight. This fact is important when reeling out 20,000 feet of payload that then has to be lifted back.

Kevlar® is a registered trademark of Du Pont Chemical Company.

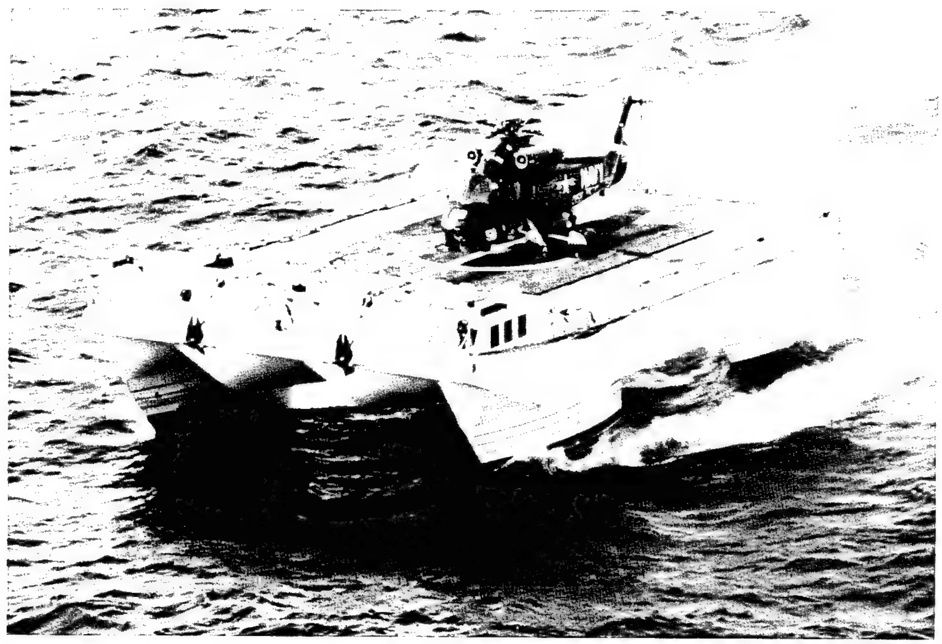
Concurrent with the development of RUWS, NUC/NOSC embarked on the development of a series of small, light-work and inspection vehicles for use in shallow waters. These "mini-CURVs" were needed for simpler, shallower tasks, for which the large CURV/RUWS-type machines proved too cumbersome or expensive. This work led to the development of the SNOOPY series of small remotely operated vehicles (ROVs).

RUWS. The remote-controlled submersible was equipped with a 35-mm still camera, underwater light, and a pair of hydraulic manipulators designed to perform a variety of tasks.



Small-Waterplane-Area Twin Hull (SWATH) Ship

The concept of reducing waterplane area to reduce ship motions dates back to 1905. While early designs might have proved acceptable at low-to-moderate speeds, most designs tended to become dynamically unstable at the higher speeds (20 knots) of interest to the Navy. A solution to this instability problem was patented by Center engineer Dr. Thomas Lang in 1971. Subsequently, the Small-Waterplane-Area Twin Hull (SWATH) ship concept was used by a team of designers at the Hawaii laboratory and the Pearl Harbor Naval Shipyard to design and specify the semisubmerged platform SSP*Kaimalino*. Following a series of trials and modifications on the East Coast, *Kaimalino* was transported to Hawaii where it since logged thousands of hours at sea in support of Navy operations.



SSP Kaimalino. *The 88-foot-long, twin-hulled* Kaimalino *serves as a range support surface craft capable of operating in high sea states.*

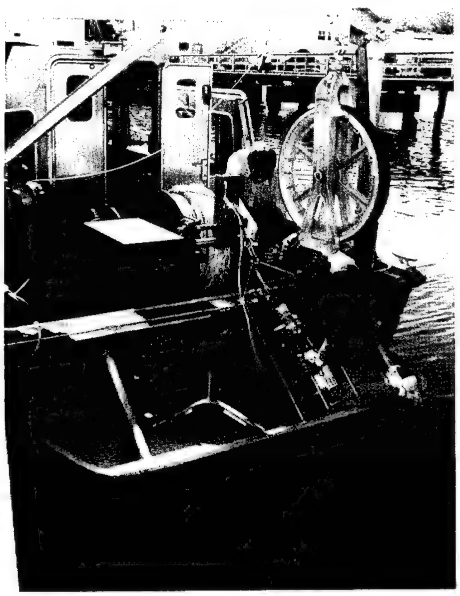
Environmental Sciences

Biological and chemical studies of the marine environment began at NUC in 1971 when CNM delegated to NUC primary responsibility for inshore and nearshore marine environment studies. NUC's study of Pearl Harbor won the Center, in 1972, the Navy's first Environmental Protection Award. Much of the Center's work in environmental assessment has involved and continues to involve the methods and techniques necessary to measure the effects on the environment of different kinds of stresses (noise, chemicals, and heat) and to research the impacts of such Navy-specific activities as dredging and in-water hull cleaning.

Starting in 1974, NUC environmental biologists and chemists working at Kaneohe Bay, Oahu, Hawaii, developed a sophisticated laboratory at the foot of the extinct Ulupau volcano to measure the effects of the Navy's presence in environmentally sensitive harbors. The Ulupau Microcosm Facility consists of a series of tanks that can replicate both a given environment and its biology by recruiting the larvae of organisms native to it. This facility continues to perform countless environmental assessments for the Navy.

In 1976, the Marine Environmental Quality Assessment (MEQA) program was begun to consolidate separate efforts into a cohesive program. The general objective was to develop the technology necessary to assess scientifically the

effects of naval facilities and operations on the marine environment. Since the methods used to study dynamic environments such as harbors and estuaries must be able to account for temporal and spatial variabilities, the emphasis was placed on multivariate, realtime systems. Such systems must also distinguish between Navy and non-Navy sources of environmental stress.



Scientists configuring a new MESC for measurement of pollutants in Navy harbors and bays. (1989 photo)

In 1978, NOSC began work on a field survey that combined as many relevant measurement systems as practicable for the conduct of multivariate, realtime surveys. This system enabled researchers to understand spatial (and temporal) variabilities and relationships among various environmental parameters. Physically, the field survey system was located in a dedicated Marine Environmental Survey Craft (MESC), a converted houseboat equipped with sensors and processing equipment. NOSC also developed a portable, modular version of the MESC systems, including the Realtime Data Analysis System, a transportable, microcomputer-based assessment system normally installed on a survey platform vessel. The MESC surveyed the Navy's *Trident* submarine base at Kings Bay, GA, as well as the harbors of San Diego, CA; Norfolk, VA; Charleston, SC; and Pearl Harbor, HI.

The MEQA program provided direct assistance to the Fleet on environmental problems. Specific issues ranged from consulting with naval stations and engineering field divisions, to writing environmental impact statements, to conducting a comprehensive study of the environmental impacts of in-water hull cleaning. Further environment studies have been possible, in large measure, because of the technologies originally developed in the MEQA program.

Undersea Surveillance

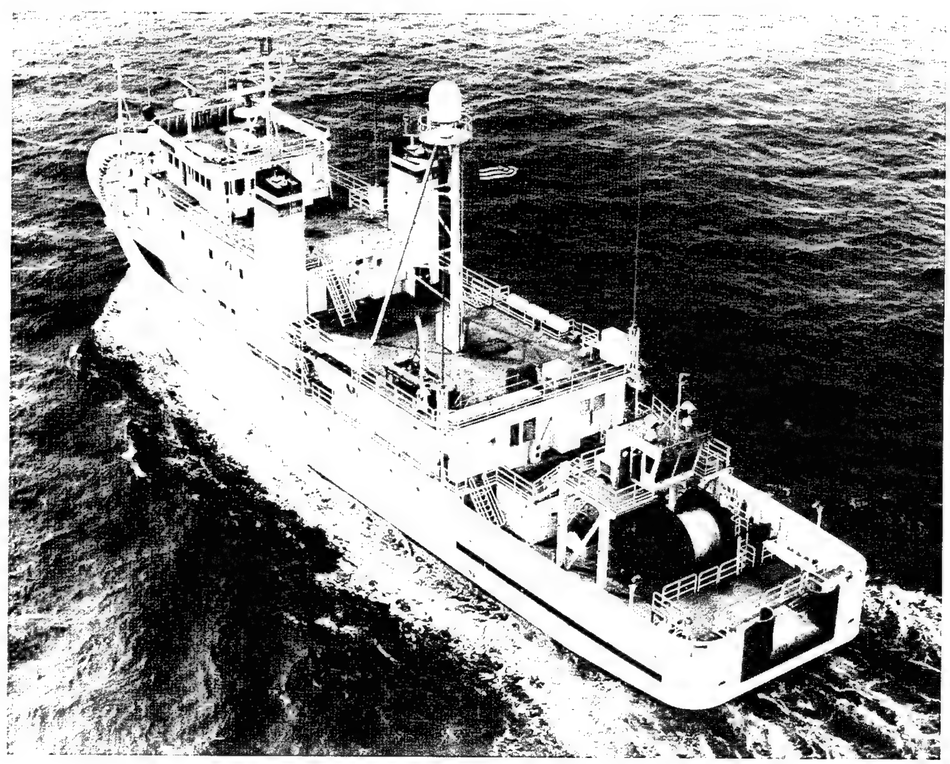
In 1970, NURDC took over responsibility for the new field of undersea surveillance, essentially the long-range detection and monitoring of submarines. Detecting submarines was an old problem, but since 1945, submarines had grown quieter, faster, and more numerous. Submarines no longer had to run on the surface to recharge their batteries. Thus, the chances for radar to detect submarines dropped significantly, and acoustics became an even more important means of detection.

By 1970, the Navy's undersea surveillance capabilities consisted of arrays of hydrophones of the Sound Surveillance Underwater System (SOSUS) cabled to shore-to-shore processing stations. To combat the trends of increasing ambient noise in the ocean and quieter Soviet submarines, the U.S. Navy developed a program to enhance the shore processing capabilities of SOSUS by adding modern digital signal processing, communications, and information-processing systems. NUC and later NOSC have been involved in the development, installation, and performance analysis of the enhancements to the computer-based subsystems for SOSUS. These upgrades, collectively defined as the SOSUS Phase I and Phase II Backfit Programs, have given the U.S. Navy an increased capability to locate and localize Soviet submarines.

In the early 1970s, Hank Aurand (then at NAVMAT but shortly thereafter at NUC) proposed that a valuable adjunct to the SOSUS system would be a mobile SOSUS that could replace a disabled SOSUS array or could provide surveillance in waters far from the fixed SOSUS arrays. NUC demonstrated that the idea was feasible with the Large Aperture Marine Basic Data Array (LAMBDA). LAMBDA adapted commercial geophysical exploration equipment from offshore workboats to establish both a database and operational procedures.

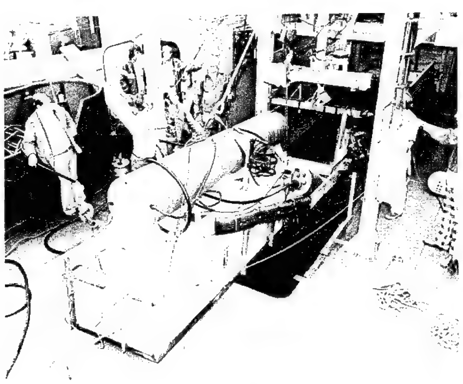
This work and a series of towed array projects at NUC/NOSC led to the development of the mobile SOSUS-like towed array called the Surveillance Towed Array Sensor System (SURTASS). SURTASS was designed to be a long-range passive receiver operated from special ships dedicated exclusively to the system. These ships, known as the T-AGOS class, not only towed the array but housed data-processing equipment to distinguish signals from background noise. Moreover, T-AGOS ships could relay their data to shore processing facilities by using satellite communications links, also developed at NOSC. The shore sites could correlate the data with information developed from other T-AGOS ships, SOSUS arrays, tactical sonars, or other sources. SURTASS passed both its technical and operational evaluations in 1980. Several SURTASS T-AGOS ships have since been delivered to the Fleet, and SURTASS is revolutionizing undersea surveillance.

USNS Stalwart *(T-AGOS).* Stalwart *was the first ship equipped with SURTASS and used for flexible, worldwide, long-range acoustic surveillance.*

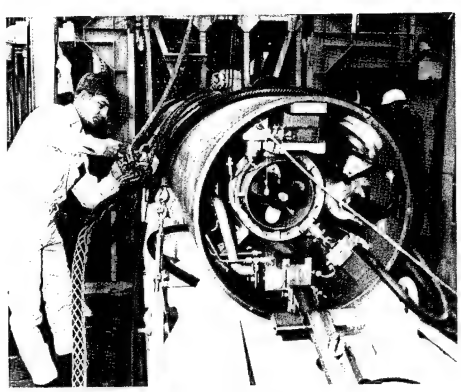


Mobile Submarine Simulator (MOSS)

Beginning in 1972, NUC updated a sound beacon concept developed by NEL during World War II. Sound beacons were decoys that submarines could launch to baffle enemy sonars. NUC's Mobile Submarine Simulator (MOSS) was a torpedo-tube-launched, self-propelled decoy. The strategic objective behind MOSS was to enhance the security of the Navy's ballistic missile submarines by preventing them from being detected and tracked. Operational evaluation of the system exceeded all established goals, and the MOSS system became an integral part of all fleet ballistic missile and *Trident* submarine defensive weapon systems.



Testing of NUC's MOSS, a torpedo-tube-launched, self-propelled decoy.



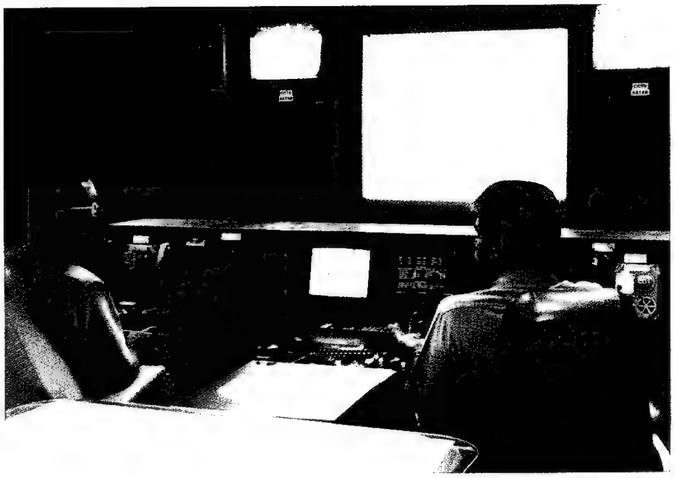
MOSS propulsion system.

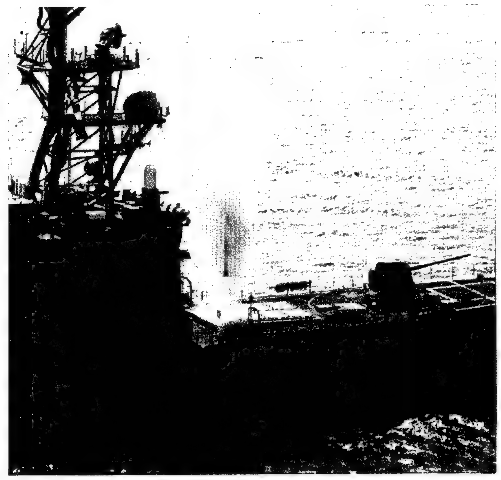
Torpedoes Mk 46 and Mk 50

Early in the 1970s, the Navy recognized that Soviet submarines were making rapid technological progress. Against faster and quieter targets, the existing Mk 46 lightweight torpedo would be less effective.

In 1975, NUC was designated lead laboratory for the new Advanced Lightweight Torpedo, Mk 50. This next-generation torpedo is designed to run faster and deeper and with greater detection range than the Mk 46. (The Mk 50 will be discussed further in the next section.)

The laboratory continued to support and enhance the Mk 46 torpedo in the parallel Near Term Improvement Program (NEARTIP). NEARTIP lasted from 1974 to 1977 and developed new electronics for the Mk 46, which today remains in service with the Fleet and with various Allied navies.





Introduction

The 1980s can be characterized as a period of transition in international security affairs. A major portion of the decade was marked by the Soviet Union's massive military buildup—consuming as much as 15 to 17 percent of its annual Gross National Product (GNP). This large, unmatched investment provided the Soviets with a position of strategic nuclear parity, quantitative conventional force superiority around the Eurasian rimland, and a modern, globally deployed navy.

During this period, there was also a revolution in military technology. Additionally, many Third World countries experienced a combination of economic growth and technological maturation.

The first objective of the Reagan administration's National Security Strategy was to restore United States military strength after a period of decline. Along with this military buildup came a bipartisan awareness of the necessity for maintaining technological superiority through coherent military research and development programs.

The consolidation of NELC and NUC came at an appropriate time. The consolidation provided increased flexibility and larger blocks of funding for broader and more comprehensive investigations. More than any other benefit, consolidation of the two Centers produced a broad-spectrum system capability in intelligence, surveillance, sensors, C^3, undersea weapons, and countermeasures in support of the Navy's mission of controlling the seas.

Throughout the 1980s, NOSC continued to serve the U.S. Navy through state-of-the-art efforts in research and development. Important new systems developed in NOSC's major product lines included the Advanced Combat Direction System (ACDS) and the Tactical Flag Command Center (TFCC); submarine broadcast, ship-to-shore, and satellite communications systems; over-the-horizon radars and the Integrated Undersea Surveillance System (IUSS); and the Mk 50 torpedo and the Mk 116 ASW Control System. Additionally, NOSC planned and coordinated submarine ice exercises in the Arctic and developed an ice-avoidance sonar.

This past decade was also a period during which NOSC experienced change and innovation administratively. Some administrative programs such as the Personnel Demonstration Project gave NOSC special visibility throughout the Federal workforce. Other administrative changes explained in this section were more specific to DoD or NOSC.

Center Reorganization

Effective 1 July 1984, NOSC implemented a reorganization plan aimed at enhancing efficiency by reducing layers of management. Since its beginning, NOSC had six directorates: five in technical areas and one overseeing support activities. These directorates, under the cognizance of Technical Director Dr. H. L. Blood, had helped to smooth the merger over the first 7 years. In the new organizational structure, the directorates were abolished, and the technical departments were given increased authority. R. M. Hillyer, now Technical Director of NOSC replacing Dr. Blood, advocated the plan as a means to push decision-making responsibility down to appropriate levels, thus allowing project personnel to concentrate more effectively on their technical work.

The year 1984 also brought a restructuring of the Arctic Submarine Laboratory due to an increased emphasis on arctic research and expansion of fleet support activities. A career submariner, Captain E. J. "Jack" Sabol, was appointed Director, reporting directly to the NOSC Commander and Technical Director. (The Arctic Submarine Laboratory Director would also serve as a member of the staffs of the Commanders of both the Pacific and Atlantic Submarine Forces.) Dr. Waldo Lyon was appointed Chief Engineer and Senior Scientist of the Arctic Submarine Laboratory.

Personnel Demonstration Project

Since 1980, both NOSC and the Naval Weapons Center (NWC) at China Lake have participated in a Personnel Demonstration Project. The project is an innovative revision of basic personnel management systems and is intended to simplify those systems, make them more responsive to Center needs, and enhance recruitment and retention. The Personnel Demonstration Project as implemented at NOSC provides simplified position classification and performance appraisal, links performance with pay, and emphasizes performance-based retention. At the heart of the system are broad paybands arranged in five career paths with progression closely related to work performance.

NOSC uses the Personnel Demonstration Project in the normal conduct of business, participates in its evaluation as a potential government-wide personnel system, and provides information to other government agencies about the system. The Department of the Navy received the Ribicoff/ Percy Award for excellence in Civil Service Reform Implementation for the NOSC/NWC-sponsored Personnel Demonstration Project.

Public Law 100-566, signed 11 November 1988, extended the Personnel Demonstration Project until 30 September 1995.

Reorganization of Navy Laboratories

Reassignment from NAVMAT to CNR

In April 1985, the Secretary of the Navy (SECNAV) disestablished the Naval Material Command to which the Center and seven other Navy laboratories (apart from NRL and the Naval Ocean Research and Development Activity [NORDA]) had reported since 1964. Under the resulting new organization, the NAVMAT laboratories were reassigned to the Chief of Naval Research (CNR).

As part of this reorganization, SECNAV directed a major change in management for the Navy exploratory development (6.2) program. CNR was directed to establish a block programming management structure with the Navy laboratories and centers, instead of the systems commands, as program claimants. The systems commands would no longer be involved in directing 6.2 work, but the Office of Naval Technology (ONT), under CNR, would continue to provide top-level management for the approximately $500 million in Navy 6.2 programs. The laboratories and centers were themselves to perform the detailed planning and execution of the programs.

Reassignment from CNR to SPAWAR

In February 1986, SECNAV transferred the management of the Navy R&D centers from CNR to the Commander, Space and Naval Warfare Systems Command (SPAWAR). Effective 24 February 1986, SPAWAR assumed management responsibilities for NOSC, seven other Navy R&D centers, four affiliated university laboratories, and the office of the Director of Navy Laboratories (DNL). The objective of the transfer was to align the laboratories more appropriately with SPAWAR's material and technical support organization, to streamline administration, and to bring the centers more effectively under the Navy's top-level engineering managers.

NOSC Strategic Plan

Based on decisions made during a strategic corporate planning retreat held on 19 and 20 July 1988, NOSC management prepared the NOSC Strategic Plan. The plan established long-range strategic thrusts based on NOSC's corporate values and vision of the future.

The NOSC Strategic Plan addressed eight business thrusts: (1) command and control, (2) communications, (3) surveillance, (4) integrated ASW, (5) arctic warfare, (6) ocean science and engineering, (7) intelligence, and (8) warfare systems architecture and engineering (WSA&E).

The plan also addressed the Center's technology base thrusts since the technology base is an essential part of all future systems.

Finally, the plan addressed management thrusts that supported NOSC's technical thrusts. NOSC pledged to continue to foster a corporate team spirit, to encourage excellence, and to create a work environment conducive to creative and productive efforts.

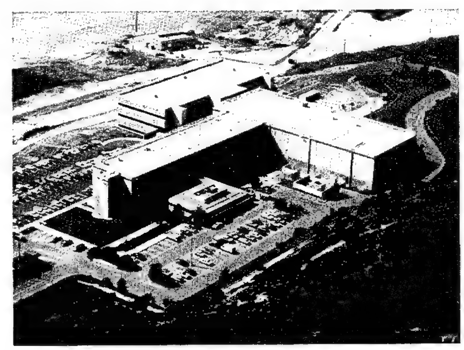
Issued in July 1989, the NOSC Strategic Plan defined areas of primary focus in the future:

> *We intend to make NOSC the lead laboratory for C^3 and be recognized as a world-class center for information warfare. We also intend to continue our leading role in ocean surveillance. We will strengthen this role by expanding the aerospace aspects of surveillance. We have always seen the need to provide the Navy with follow-on generations of superior air- and surface-launched undersea weapons systems; now we see an even more important need to develop integrated ASW systems. To complement and support these efforts, we will continue to provide leadership in arctic submarine warfare and ocean science and engineering. Because of our broad expertise, mission, and support areas, we will support the collection, processing, and dissemination of intelligence. Finally, we will support these efforts by building and coordinating an even stronger technology base. These efforts define our areas of primary future focus and form the basis for our strategic business thrusts.*

New NOSC Facilities

Ocean Surveillance Laboratory, Building 605, Seaside

Opened in 1982, Building 605, the Ocean Surveillance Laboratory, provides for the development, physical integration, and testing of surveillance systems on a total platform and multiplatform basis. The facility provides for near real-time message processing, realtime signal processing and information processing, and the merging of hardware and software design. Adjacent to the NOSC C^3 SITE, Building 605 provides an electromagnetically shielded, realistic operational environment with line-of-sight access to fleet operating areas.



Ocean Surveillance Laboratory, Building 605, Seaside. Shown adjacent to the C^3 SITE.

In 1983, the Acoustic Research Center (ARC) was relocated to Building 605 from Moffett Field, where it had operated as a Defense Advanced Research Projects Agency (DARPA) facility. The ARC greatly enhanced the scope and capability of NOSC's on-site data links and reduced the need for remote installations and linkages. The ARC was later expanded to include all source surveillance data, and the facility is now known as the Surveillance Test and Integration Center (STIC).

Ocean Sciences Laboratory, Building 111, Bayside

Completed in 1986, Building 111, the Ocean Sciences Laboratory, provides unique facilities for RDT&E in marine biology, environmental sciences, and radiation physics. The laboratory has filtered salt water and includes special facilities for work with marine organisms; laboratories for oceanographic research, chemistry, and biochemistry; laboratories for nonmedical biotechnology studies; and laboratories with analytical instrumentation facilities for environmental research and monitoring. NOSC is the only Navy laboratory involved in marine environment studies. Building 111 houses state-of-the-art chemical and biological laboratories for such studies. Also, radio frequency interference (RFI)-shielded spaces within the facility provide for R&D in lasers and microelectronic systems.

Ocean Sciences Laboratory, Building 111, Bayside.

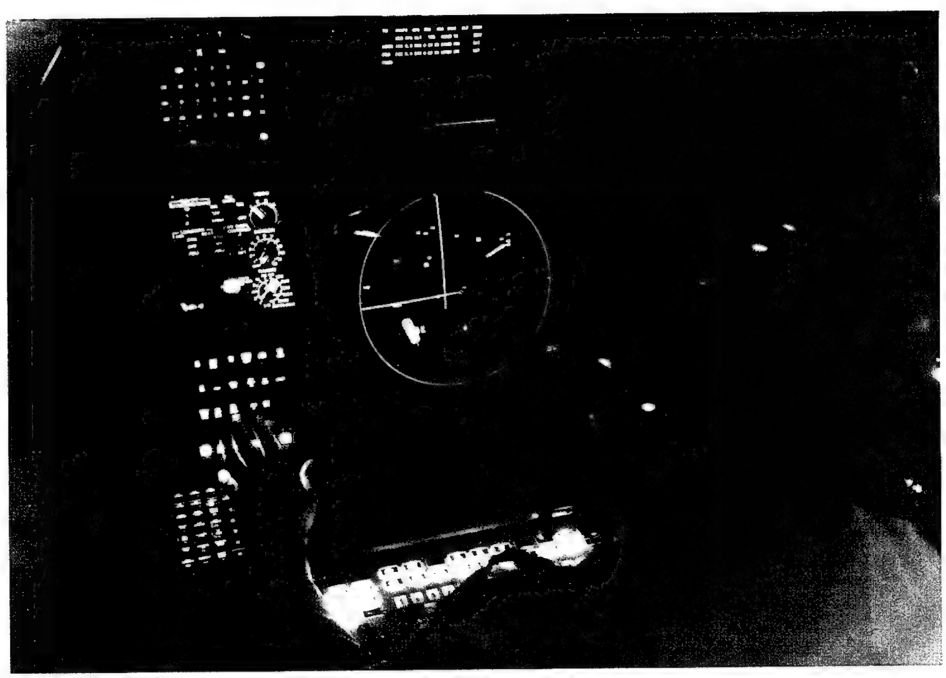
New Systems and Research

Advanced Combat Direction System (ACDS)

NOSC has continued the work of NEL and NELC in conducting research on tactical data systems. A key element in the continuing improvement of the Navy Tactical Data System (NTDS) is the Advanced Combat Direction System (ACDS) Block 1 upgrade. This upgrade has significantly enhanced NTDS in the areas of sensor management, tactical data exchange, warfare area coordination, and system coordination. NOSC began development of ACDS Block 1 in October 1981. Once ACDS Block 1 is introduced to the Fleet, subsequent improvements will be deployed in roughly 3-year increments. Such enhancements will enable all units of the Fleet to have similar tactical command programs to support command needs.

NOSC work in tactical data systems also includes the Flag Data Display System (FDDS), which is a subsystem of the Tactical Flag Command Center (TFCC) developed in the mid-1970s. The FDDS provides access to force information held by Navy command and control (C^2) systems ashore. Fleet installation of this upgraded system has begun.

ACDS. A replacement for NTDS, ACDS provides force-level command decision systems and combat direction systems to non-Aegis ships.



Enhanced Verdin System (EVS)

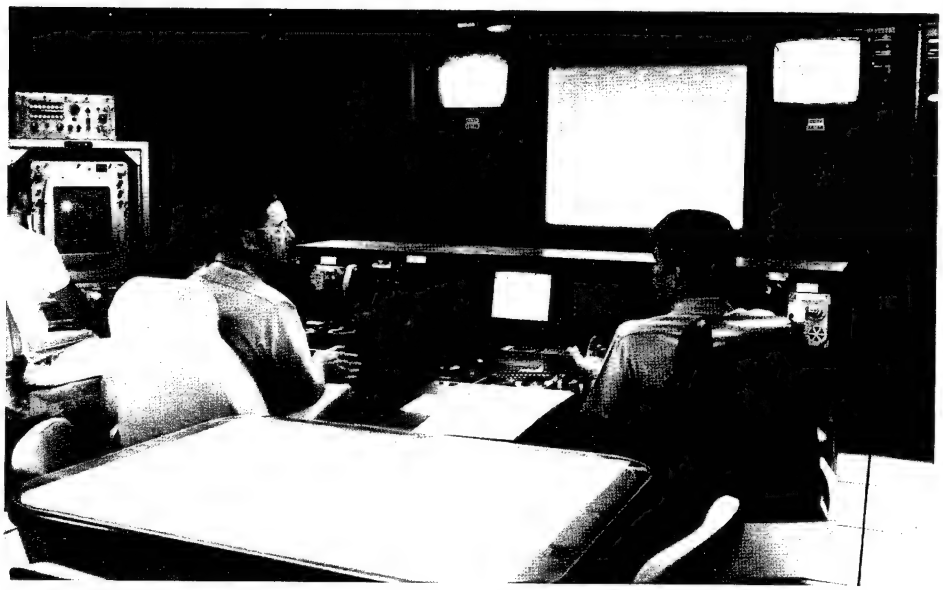
Throughout the 1980s, NOSC personnel have played a major role in the development of the Enhanced Verdin System (EVS), designed to update the submarine communications system developed in the 1960s.

EVS is more powerful and has a much higher capacity to process digital communications that improve connectivity, reliability, accuracy, and speed of delivery of VLF/LF traffic to naval strategic

forces deployed around the world. This EVS replacement system provides vastly improved strategic command and control communications from the Joint Chiefs of Staff and the National Command Authority to submarines and aircraft.

Before fleet installation, EVS was subjected to rigorous technical testing in the Atlantic Ocean to demonstrate the system's reliability in transmitting and receiving emergency action messages.

EVS has now been installed on all *Trident* submarines and Atlantic Fleet ballistic missile submarines (nuclear propulsion) (SSBNs).



Mock-up, located at NOSC, of the TFCC aboard USS America *(CV 66). TFCC is the primary battle station for the embarked battle group commander and his staff.*

Secure Conferencing Project (SCP)

The Secure Conferencing Project (SCP) supports unified commanders worldwide with better data and information flow. Other conferencing systems in use must route all secure voice communications through a central bridge. For example, users dial into a central location where connections are made manually. However, with the advent of the Secure Conferencing Project, operation is totally automatic; a person picks up the phone and dials, as with a conventional phone. To achieve this level of automation, SCP uses satellites and electronic conference directors as the conferencing bridges and switches via a distributed architecture.

In addition, SCP features a dial tone, a busy signal, and a distant ring. The graphics mode allows teletype data to be transmitted as easily as facsimile copy, with the same degree of security.

NOSC shipped the first complete suite of SCP equipment in September 1985. SCP represents a significant achievement for several reasons. The system was composed of new equipment, and SCP was the first secure communications system to use a Defense Satellite Communications System SHF link. SCP was also the first system to employ jam-resistant, secure communications, spread-spectrum satellite modems to provide nuclear-survivable connectivity.

NOSC is now spearheading enhancements to SCP, and the system is being installed in over 40 command centers worldwide.

Satellite Laser Communications (SLC)

In today's Navy, communications to a nuclear attack submarine must be conducted at or near the surface of the ocean due to the poor propagation of radio frequency (RF) energy through seawater. Because of this requirement, all present communication connectivity is in some manner submarine initiated. The Satellite Laser Communication (SLC) program was originated to develop one-way unscheduled communications to submarines at depth and speed.

Communications to submarines at depth is possible due to a window in the transmission characteristics of seawater. This window occurs in a narrow band in the blue-to-green visible light region of the electromagnetic spectrum. Proper choices of laser transmitters and matching optical receivers allow communications to operational depths.

NOSC, with over a decade of experience in submarine laser communications research, demonstrated in 1988 that blue laser and receiver communication technology was suitable for transition to a space-based SLC system.

Laser transmitter installed on Lockheed P-3C aircraft. In 1988, NOSC demonstrated blue laser and receiver communications technology suitable for transition to a space-based, SLC system.

Optical receiver installed on USS Pintado *(SSN 672) for the 1988 blue laser and receiver communications technology demonstration.*

The difficult question remaining for submarine laser communications is that of affordability. The costs of a satellite system are high. In 1989, NOSC's Research, Evaluation, and Systems Analysis (RESA) facility was used to provide interactive wargaming and analysis of the impact of SLC on operations. It is anticipated that continuing wargaming under varying scenarios and capabilities will assist in setting submarine laser communication requirements.

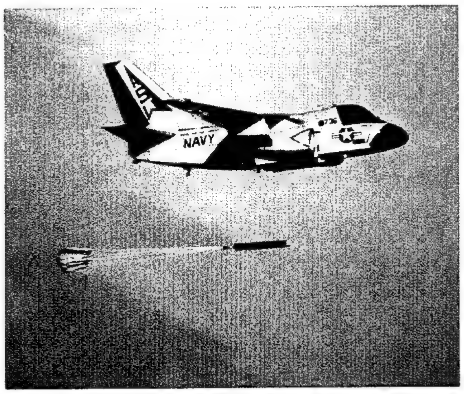
RESA. A flexible and capable battle force simulation system, the RESA facility supports interactive wargaming as well as technology assessments, interoperability testing, and warfare system architecture assessments.

Surface- and Air-Launched Undersea Weapon Systems

The Torpedo Mk 46 remains the Navy's payload in all surface- and air-platform ASW systems, and it continues to be the standard in lightweight antisubmarine torpedo warfare throughout the free world. Introduced in 1966, the Mk 46 has undergone a series of improvements that will prolong its life into the next century. The Near-Term Improvement Program (NEARTIP) upgraded the Mk 46 Mod 1 and Mod 2 torpedoes to the Mk 46 Mod 5 torpedo. Later upgrades to the NEARTIP program were implemented into the Fleet in the mid- and late-1980s and included the shallow-target upgrade and the shallow-water upgrade. NOSC, as the technical direction agent and design agent for the Mk 46, provides engineering support that encompasses a wide range of efforts, including overall production engineering, product assurance, acceptance test and evaluation, and product improvement. Approximately 750 U.S. Navy aircraft and 250 ships employ the Mk 46 in antisubmarine warfare.

NOSC is the lead laboratory for the Torpedo Mk 50, which will eventually replace the Mk 46. The Center monitors developments in U.S. torpedo systems and tactics as well as in enemy threats to assess their impact on the Mk 50. NOSC also directs contractor performance and coordinates with other laboratories and government agencies to integrate the Mk 50 with other weapon systems. NOSC engineers have developed the engineering change proposals to modify the attack and fire control consoles of ships to enable them to launch the Mk 50 when it becomes operational.

The antisubmarine rocket (ASROC) missile system has been deployed in the Fleet for over 30 years and is expected to continue to be a viable stand-off weapon until 2025 when the last ASROC-equipped surface ship is scheduled for retirement. Since 1980, NOSC has been lead laboratory for the Vertical Launch ASROC (VLA). The VLA is one aspect of the modular Vertical Launching System (VLS) that permits up to 61 missiles per magazine (VLA, standard missile, or Tomahawk) to be fired from individual cells. Like the other missiles, the VLA is designed for a 360-degree engagement zone and for the high rate of fire made possible



Torpedo Mk 50 launched from ASW fixed-wing platform during full-scale development testing.

VLA. The VLA is shown here on a test shot from a vertical launcher on USS Hewitt *(DD 966) off San Clemente Island.*

by the VLS on ships on which it will be installed: DD 963, CG 47, and DDG 51 classes. Just as the other missiles multiply the offensive power of these ships, the VLA vastly increases their defensive power and load-out flexibility.

The ASROC is launched from a deck-mounted launcher (Mk 165 or Mk 26) at a fixed ballistic angle, which limits the direction at which ASROC can be fired without turning the ship. The new launcher/missile design increases the original ASROC's limited engagement coverage and comparatively short range, and decreases its multiwarfare engagement limitations (such as reaction time).

Antisubmarine Warfare Control System (ASWCS)

To support the increased need for a coordinated ASW effort, NOSC began development in 1980 of the Antisubmarine Warfare Control System (ASWCS). ASWCS is the integrating element of the AN/SQQ-89 Surface Ship ASW Combat System. The AN/SQQ-89 provides an advanced ASW capability by bringing together the AN/SQQ-28 Light Airborne Multipurpose System (LAMPS), the AN/SQS-53B/C Hull-Mounted Sonar, and the AN/SQR-19 Towed Array Sonar. ASWCS uses data from these sensors to mutually aid in the detection, localization, classification, tracking, and prosecution of underwater targets in greater numbers and at greater ranges than existing systems.

NOSC is the technical direction agent for the ASWCS Mk 116 Mod 7 portion of the AN/SQQ-89 system and is the design agent and life-cycle management agent for all remaining Mk 116 mods. Currently NOSC supports 13 different baseline programs for shipboard use in this effort. During 1989, 11 new software program deliveries were made to fleet units to provide additional capabilities such as VLA and improved signal processing.

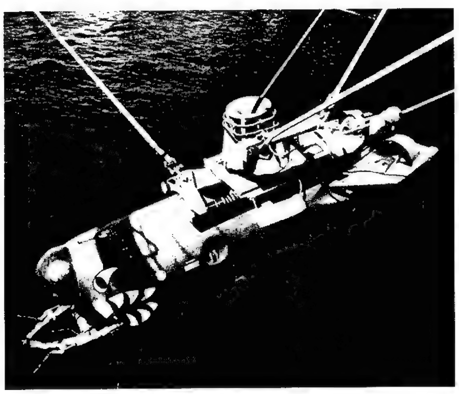
ASWCS Mk 116. The Mk 116 consists of tactical software implemented in a Navy standard AN/UYK-7 or AN/UYK-43B computer interfaced with Navy standard peripherals and display consoles.

Mine Neutralization System (MNS)

The NOSC-developed Mine Neutralization System (MNS) evolved from extensive ROV work done at NOTS Pasadena and NUC San Diego. The MNS vehicle was envisaged from the start as deployable from a fleet ocean minesweeper and able to locate and classify mines. It would then be able to drop a charge near a bottom mine or attach a cable cutter to a moored line.

Such capabilities would give the Fleet the long overdue ability to neutralize the modern mine threat. Technical evaluation and operational testing of the MNS were completed in 1982. A production contract for 12 systems and 27 submersible vehicles was awarded to

Honeywell Corporation in July 1984. The MNS went into production in 1985, and late in 1986, the first units were delivered to shipyards. In 1987, the first MNS (the AN/SLQ-48) was installed aboard the mine countermeasures ship, USS *Avenger* (MCM 1), and other units continue to be delivered to the Fleet.



MNS. The first MNS was installed aboard USS Avenger *(MCM 1) in 1987 to provide the ability to neutralize modern mine threats.*

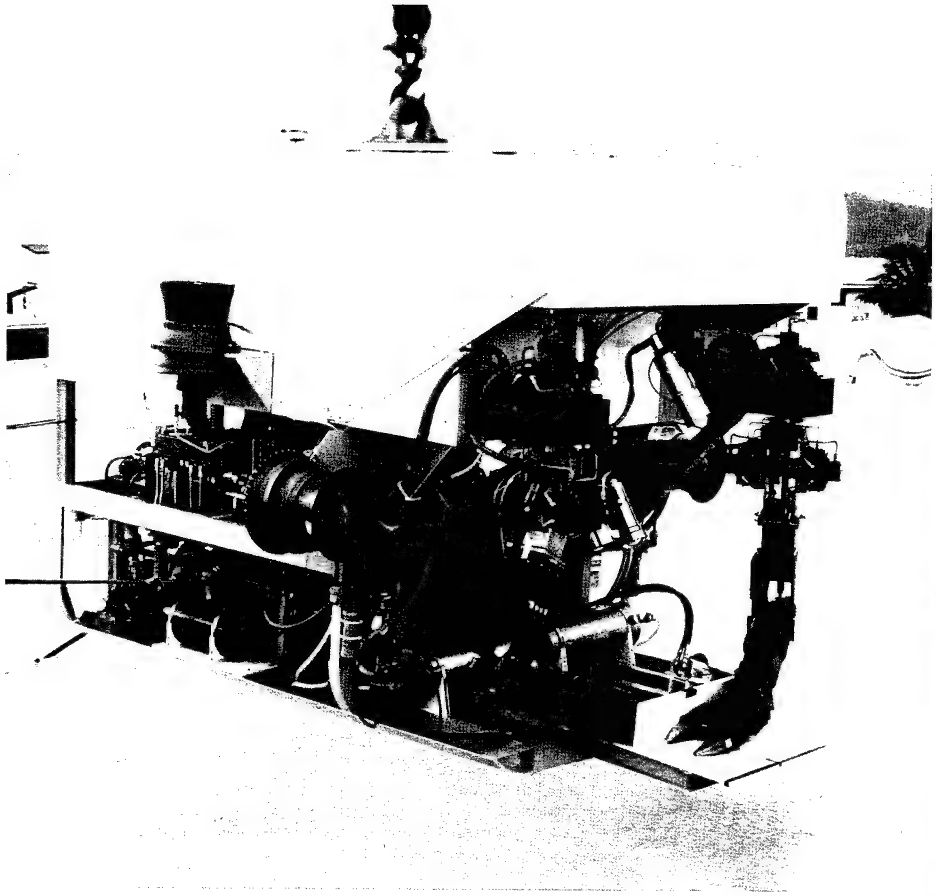
Unmanned, Undersea Vehicles (UUVs)

Two unmanned, undersea vehicles (UUVs) have been developed by NOSC in-house as one-of-a-kind units for operation by the Submarine Development Group One in San Diego.

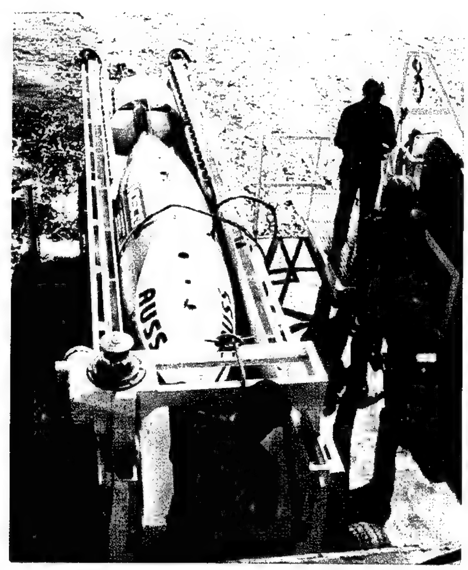
The first, the Advanced Tethered Vehicle (ATV), began as a design study in 1980. The ATV provides a deep-ocean work capability for the Navy: primarily, the recovery of objects and equipment. The ATV is a remotely operated, submersible work system consisting of a neutrally buoyant vehicle, a tether cable, a surface control station, launch/recovery and cable handling equipment, power generators, and maintenance shelters. The ATV is designed to be easily transportable and operable from ships that meet specific requirements for deck space and stationkeeping. The ATV carries manipulators, tools, and sensors, including TV cameras and sonar. During 1985, operational tests of a prototype system were completed, and the vehicle made a record dive of 12,100 feet. Based on data developed during these tests, NOSC began design of the fleet system in 1986.

The production ATV represents the culmination of vehicle system experience at NOSC. Both formal and informal reviews were established to take advantage of the background of NOSC operators and designers. The system design has been a careful balance of the tradeoffs between technology, operability, and performance. The principal technical advancement is the tether cable, its optical fibers, and the associated digital telemetry link. The ATV is capable of performing fleet missions to depths of 20,000 feet.

The complementary system to the ATV is its companion Advanced Undersea Search System (AUSS). The AUSS is an acoustically controlled, free-swimming ROV. The primary innovations of the AUSS include its acoustic telemetry system, its graphite composite hull, and its state-of-the-art microelectronic processing circuitry. Acoustic telemetry frees the vehicle from the constraints of a tether and enables the AUSS to transmit digitized data from operating depths. The AUSS can be used to locate an object to depths of 20,000 feet, and the cable-powered and controlled ATV can be used to work on the object once it is found.



ATV. The ATV is a remotely operated, submersible work system that provides a deep-ocean work capability for the Navy.



AUSS. An acoustically controlled, free-swimming ROV, AUSS can be used to locate objects to depths of 20,000 feet.

Submarine Arctic Warfare

The Chief of Naval Operations (CNO) officially added submarine arctic warfare to the NOSC mission statement in April 1980. By the early 1980s, submarines of the Soviet Navy were discovered in the Arctic, and the work by Dr. Waldo Lyon and the staff of the Arctic Submarine Laboratory (ASL) suddenly demonstrated its full significance.

Throughout the decade, the ASL continued to support the CNO's Arctic Warfare Initiative by serving as lead laboratory for highly successful arctic submarine ice exercises (SUBICEXS). During this time, the ASL also conducted laboratory and field research to provide submarines with maximum capability to operate and exploit all ice-covered seas during all seasons.

A major NOSC program completed in the 1980s to support the Navy's Fleet operations in the Arctic was the improvement to the AN/BQS-14 sonar for *Sturgeon*-class submarines. The AN/BQS-14 sonar is a now-obsolete design (but the best available when that class of submarines was designed in the mid-1960s). The Arctic Pulsed Experimental (APEX) sonars are "add-on" units to the AN/BQS-14 sonars.

The APEX sonars upgrade the AN/BQS-14s and solve several operational problems. The "add-on" approach of the APEX produced an up-to-date sonar in less time and at much lower cost than would have been possible with development and production of a completely new ice-piloting sonar. Only 18 months passed from the time the submarine force asked for help to the first APEX test in the Arctic. The ASL completed delivery of the APEX IIA sonars to the Fleet in 1988. The APEX unit completely solved the operational problems of the AN/BQS-14 and was met with enthusiastic acceptance by the submarine community. Every *Sturgeon*-class submarine deploying to the Arctic has been so equipped.

NOSC is now developing an APEX-like "add-on" sonar for the AN/BQS-15 sonars onboard *Los Angeles*-class submarines. This program is called SPECTRA (Special Transmissions). The prototype SPECTRA sonar was "shop tested" in 1988 and completed its first sea trial in 1989.

USS Queenfish *(SSN 651) during arctic deployment.*

The Future

The Naval Ocean Systems Center has a clear tradition of excellence, and the present situation in the world will demand that we strengthen that tradition. We can all take some measure of hope in what we see happening in the world today, as the Cold War ends and the bankrupt ideology that supported that war begins to collapse on itself. We now live in a world with a greatly reduced threat of nuclear holocaust, a world that promises some of the blessings we already enjoy to millions of others who have never known these blessings.

We, who work at DoD laboratories like NOSC and who develop much of the technology that makes our own nation great, can take pride in what we have accomplished. The Soviet Union, after decades of spending too much of its energies, its resources, and its people on massive military development, has recognized that it cannot compete with us in both the military and economic arenas. The military systems we develop are the products of a culture combining free enterprise and democracy, and that combination is without equal. Our military systems have provided us the security necessary to allow our economic and political systems to mature and shine. As we look back on the history that led to NOSC's 50-year milestone, we see impressive contributions to the military strength of our nation, contributions that helped bring about the very changes we see in the world today.

The technology development that has been our reason for existence, not only supported the nation's military might, but its economic and industrial strength as well. Science and technology know no boundary between military and civilian enterprise, and we at NOSC have contributed our share, as evidenced clearly by the more than 400 patent applications we have filed in the past 10 years.

Our first 50 years began with the challenge of World War II and have ended with the end of the Cold War; we can truly say we helped the Navy and the nation meet that challenge. Our second 50 years begin with a challenge of equal magnitude: the despair and virtual slavery in Eastern Europe have been replaced by hope and promise of freedom, but the relative stability of a bi-polar world dominated by two superpowers has been replaced with a good deal of uncertainty and instability.

We live in a world in which superpower influence has diminished, a world in which a number of countries that previously looked to either the U.S. or the U.S.S.R.

for leadership now boast strong military, political, and economic systems of their own. And, in many of the smaller countries, the destabilizing influence of the end of the Cold War has increased the possibility of violent regional conflict, based as much on economic and religious factors as political ones.

In this new world, the role of research and development will be greater than ever. It is the basis for our military strength, and the most fundamental element of our economic strength. If that challenge were not great enough by itself, we face it at a time when the public and the Congress are clamoring for a peace dividend and seeking it through a substantial decrease in the defense budget. The result will be a draw-down in the size of the defense industry and a shift away from the tech base and systems development within the private section so essential to our country's military strength.

From an economic and military standpoint, the efforts of the DoD research laboratories, particularly in the high technology area, thus become significantly more important. As the potential returns to the defense industry from basic research and development appear to be dwindling, fewer and fewer contractors will be risking capital investment on military programs, and there will be increasing requirements for laboratories like NOSC to make up the shortfall. To support a modern Navy and an island nation in an uncertain world, the need for science and technology, the need for scientists and engineers, will be greater than ever.

Throughout our five decades of service to the Navy, this laboratory has pursued excellence in a variety of technical fields. We must not only continue that pursuit; we must intensify it. While we can expect to see changes in the way we do business, as the world forces us to change, our role will remain strong. We face a future every bit as exciting and challenging as our past. As the employees of this laboratory met the challenges of World War II, Korea, Vietnam, and the Cold War, we must look ahead to meet the challenges of the new century so rapidly approaching. The work that we do here in our major mission areas is of essential importance to the United States Navy, and we must pursue it with the same enthusiasm and dedication we've shown for the past 50 years.

Captain J.D. Fontana
Commander
Naval Ocean Systems Center

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Commanding Officers and Technical Directors of NOSC and Its Predecessor Agencies, 1940-1990

Military		Civilian	
Navy Radio and Sound Laboratory (NRSL)			
		Chief Scientist, UCDWR at NRSL	
CDR J.B. Dow	1940		
CAPT W.J. Ruble	1940-1942	Dr. V.O. Knudsen	1941-1942
CAPT P.H. Hammond	1942-1945	Dr. G. Harnwell	1942-1946
CAPT P.W. Hord	1945	Dr. F.N.D. Kurie	1946
		Marine Physical Laboratory (MPL)	
		Dr. C.H. Eckart	1946
Navy Electronics Laboratory (NEL)			
CAPT P.W. Hord	1945	**Superintending Scientist, NEL**	
CAPT R. Bennett, II	1946-1950	J.P. Maxfield	1948
CAPT D.P. Tucker	1950-1953	**Technical Director**	
CAPT H.E. Bernstein	1953-1956	Dr. F.N.D. Kurie	1953-1960
CAPT G. Hunter	1956		
CAPT J.M. Phelps	1956-1960		
CAPT J.H. Allen (Acting)	1960	Dr. R. Christensen (Acting)	1960-1967
CAPT F.B. Herold	1960-1962		
CAPT H.C. Mason	1962-1965		
CAPT W.R. Boehm	1965-1967		
Naval Command Control and Communications Laboratory Center (NCCCLC)			
CAPT W.R. Boehm	1967-1968	Dr. R. Christensen	1967-1968
Naval Electronics Laboratory Center (NELC)			
CAPT W.R. Boehm	1968-1969	Dr. R. Christensen	1968-1969
CAPT M.D. Van Orden	1969-1972	C.E. Bergman	1969-1977
CAPT N.D. Harding, Jr.	1972-1975		
CAPT R.R. Gavazzi	1975-1977		

Military		Civilian	

Naval Ordnance Test Station (NOTS)

RADM W.G. Switzer	1947-1949	Dr. T.L.E. Thompson	1945-1951
CAPT W.V.R. Vieweg	1949-1952	Dr. F.W. Brown	1951-1954
CAPT P.D. Stroop	1952-1953		
CAPT D.B. Young	1953-1955	Dr. W.B. McLean	1954-1967
CAPT R.F. Sellars	1955		
CAPT F.L. Ashworth	1955-1957		
CAPT W.W. Hollister	1957-1961		
CAPT C. Blenman, Jr.	1961-1964		
CAPT L. Grabowsky	1964		
CAPT J.I. Hardy	1964-1967		
CAPT G.H. Lowe	1967		

Naval Undersea Warfare Center (NUWC)

CAPT G.H. Lowe	1967-1969	Dr. W.B. McLean	1967-1969
CAPT C.B. Bishop	1969		

Naval Undersea Research and Development Center (NURDC)

CAPT C.B. Bishop	1969-1972	Dr. W.B. McLean	1969-1972

Naval Undersea Center (NUC)

CAPT C.B. Bishop	1972	Dr. W.B. McLean	1972-1974
CDR W.J. Gunn	1972		
CAPT R.H. Gautier	1972-1975	Dr. H.L. Blood	1974-1977
CAPT R.B. Gilchrist	1975-1977		

Naval Ocean Systems Center (NOSC)

CAPT R.R. Gavazzi	1977-1979	Dr. H.L. Blood	1977-1983
CAPT S.L. Guille	1979-1982		
CAPT J.M. Patton	1982-1984	D.J. Wilcox (Acting)	1983
CAPT F.M. Pestorius	1984-1986	R.M. Hillyer	1983-Present
CAPT E.G. Schweizer	1986-1989		
CAPT J.D. Fontana	1989-Present		

Land Ownership and Events on Point Loma: 1542-1977*

1542 **28 September.** The first European to discover the coast of California, Juan Rodriguez Cabrillo, a Portuguese navigator sailing for Spain, landed on Point Loma near Ballast Point at the entrance to the "very good enclosed port" that he called San Miguel, and claimed possession of Alta (Upper) California in the name of the King of Spain and the Viceroy of Mexico.

1602 **10 November.** Sebastian Vizcaino, commanding a Spanish fleet of three ships, anchored in the channel of the bay he renamed San Diego de Alcalá and landed on the small finger of land he called La Punta de Guijarros (Spanish for Cobblestone Point), later known as Ballast Point.

1796 **8 November.** The Spanish fortification on Ballast Point, El Fuerte de Guijarros, was dedicated. Officially known as El Castillo San Joaquin, it consisted of a parade ground and flagpole, barracks, powder magazines, and (uncompleted) cannon emplacements. No Spanish garrison was maintained here after 1835.

1821 **24 August.** The Treaty of Cordoba ended Mexico's long struggle for independence from Spanish colonial domination and created the Empire of Mexico; California was formally proclaimed a province of the Mexican Empire.

1823 **2 December.** Republic of Mexico was proclaimed, thereby overthrowing the Mexican Empire and placing California under the territorial status of a constitutional government.

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*From Flower and Roth, Environmental Consultants, *Cultural Resource Inventory: Archaeological/Historical/Architectural, Navy and Coast Guard Lands on Point Loma, California*, NOSC Contract N62474-81-C-5747, October 1982.

1846 **13 May**. War declared between the United States and Mexico.

1846 **29 July**. The war sloop USS *Cyane* anchored off Ballast Point; seamen and marines under the command of Lieutenant Stephen C. Rowan, USN, and Lieutenant William A. T. Maddox, USMC, went ashore and occupied San Diego in the name of the United States.

1846 **17 August**. Robert Field Stockton, American naval officer in command on the Pacific Coast of North America (1845-1847) prematurely declared California a territory of the United States and assumed title (never officially acknowledged) of governor and commander in chief.

1847 General Stephen Watts Kearny, recognizing the highly strategic nature of Point Loma, ordered a military reconnaissance of the peninsula that later (1849) resulted in the suggestion that the harbor entrance at Ballast Point be occupied by "permanent works of defense."

1848 **2 February.** The Treaty of Guadalupe Hidalgo ending the war between the United States and Mexico brought California under the American flag along with New Mexico, Nevada, Utah, most of Arizona, and part of Colorado; the Treaty gave the United States Government ownership of all military reservations in the former Mexican territories created under Spanish or Mexican rule and, of importance to later land grant claims, provided that the United States Government would honor those titles to property previously recognized by Mexico.

1850 **9 September.** President Millard Fillmore signed an Act of Congress admitting California to the Union; Point Loma thus became part of the 31st state.

1852 **26 February.** President Fillmore signed an Executive Order that set apart from the public domain and created a military reservation (as recommended by Secretary of War Charles M.

Conrad) that included the whole of Point Loma from the southern tip to an east-west line 1.5 miles north of Ballast Point and that extended from San Diego Bay to the Pacific Ocean. The area comprised 1300.42 acres.

1855 **15 November.** The original Point Loma Lighthouse, on grounds now within the Cabrillo National Monument, was put into service.

1870 **28 February.** The U.S. Army took possession of Ballast Point and the Point Loma Military Reservation, and evicted several companies of shore whalers who had operated seasonally on the bayside since the 1850s.

1885 President Grover Cleveland appointed a combined board of military officers and civilians, headed by Secretary of War William C. Endicott, to investigate the country's need for coastal defenses. The resulting report listed 29 locations, including San Diego, that required fortification. A few more years would pass, however, before action would be taken on the Endicott Board's report.

1891 **23 March.** The present-day Point Loma Lighthouse was put into service at the southern end of Point Loma on 11 acres of land later transferred to the Treasury Department for Coast Guard operations. This lighthouse replaced the original Point Loma light that had often been obscured by high fog.

1897 **2 March.** The Federal Government acquired exclusive legislative jurisdiction of the Point Loma military reservation from the State of California. On March 9, 1897, jurisdiction was extended to include the tidelands adjacent and contiguous to the existing reservation between the high-water mark and a line 300 yards beyond the low-water mark.

1898 **2 February.** A detachment of 20 soldiers from Battery D, 3rd Artillery, under the command of 2nd Lieutenant George T. Patterson, occupied the new coastal defense fortifications at

the hilt of Ballast Point known as the Ballast Point Battery of San Diego Barracks.

1898 The Coast Guard Ballast Point Light Station was commissioned. (It was redesigned in 1957 as a Light Attendant Station.)

1899 **22 July.** By General Order 134 of the War Department's Adjutant General, the Ballast Point fortification was named Fort Rosecrans in honor of Major General William Starke Rosecrans, an 1842 graduate of the U.S. Military Academy who, after distinguished Civil War service, was appointed Minister to Mexico. He later moved to Los Angeles, where he died in 1898.

1901 A land parcel for the Naval La Playa Coaling Station, consisting of 360.12 acres in the northern 2,900 feet of the original military reservation (excluding the Army Torpedo Station), was transferred to the Navy Department. The coaling station, the first Navy activity ashore in the San Diego area, was established in 1904 and subsequently redesignated the Naval Fuel Depot.

1901-1904 Buildings were erected. All were frame except the Post Exchange, which was brick. The Post Hospital was built by the Shaniel Brothers of San Diego; ten buildings were built by Solon Bryan and four by Charles Engebretson.

1903 **August.** Enough barracks and other essential buildings had been constructed that the entire garrison of the San Diego Barracks was transferred to Fort Rosecrans. By October, all armament recommended by the Endicott Board had been completed. These fortifications included Batteries Wilkenson, McGrath, Fetterman, and Mead, as well as storehouses and planting facilities for a mine field.

1904 The Naval La Playa Coaling Station was established.

1905 President Theodore Roosevelt convened a group similar to the Endicott Board, headed by Secretary of War, W. H. Taft. The Taft Board's function was to review the Endicott program and update its proposals. The board recommendations for Fort Rosecrans included searchlights and a new mine storehouse and planting wharf.

1905 **21 July.** One of the boilers on the U.S. gunboat *Bennington* collapsed, releasing a ton of boiling water that was instantly turned to steam that penetrated the ship. Sixty-five men died. Funeral services and a mass burial for 47 of the dead were conducted on July 23rd at the post cemetery at Fort Rosecrans. The *San Diego Union* reported:

> *All along the way carriages fell into line and by the time the promontory was reached, the procession was over a mile long.... It was 3 o'clock before the desolate cemetery, surrounded by a rude picket fence, was reached.*

1906 The Navy Radio Station Point Loma was commissioned. Even before it was formally commissioned, the station carried traffic having to do with the San Francisco earthquake. The second tidal gauge was established at La Playa Quarantine Station.

1907 The Navy Coaling Station Wharf was completed.

1909 **28 January.** A correspondence to Captain Amos A. Fries from M. C. Wilkinson, overseer, notes the following structures at the fort (fire control buildings are explicitly omitted):

Power house	Engineer's house
Old blacksmith shop	Coal shed
Bake shop	Commissary
Quarter Master storehouse	NCO Quarters
Stable	Wagon shed

Comment: "All are substantial except engineer buildings, which are fair."

Casement	Post exchange
Guard house	Enlisted men's family house

Comment: "All are substantial except last."

Garrison	5 officer quarters
Oil house	Headquarters
Hospital steward's quarters	Hospital
Fire engine house	Company barracks (2)
Ordnance storehouse	Ordnance machine shop
Post plumbing shop	4 overseers' quarters
Permanent laborers' quarters	Engineer office/workshop
Quarter Master office	Quarters (2)
Post exhange (small)	

"On Ballast Point outside of fence of lighthouse"

Engineer stable	Tool shed

"All engineer buildings are in very poor repair. The four post buildings just north of engineer buildings...also building south of guard house and the post plumbing shop are worthless; altho [sic] lack of quarters renders them necessary at present."

1909 The original Army Torpedo Station was transferred to the Navy Department.

1910 A road surfaced with decomposed granite was built along the crest of the point out to the lighthouse.

1912 Navy Radio Point Loma was assigned the call letters NPL.

1913 **14 October.** President Woodrow Wilson signed a proclamation setting aside 21,910 feet of land surrounding the original Point Loma Lighthouse as a historic landmark to commemorate the landing of Cabrillo.

1914 Congressman William Kettner secured an appropriation of $45,000 for the improvement of the wharf and $50,000 for the construction of fuel oil tanks at the Naval Coaling Station. A Board of Officers recommended further improvements of Fort Rosecrans that included two new mortar batteries and an extensive system of fire control stations and searchlights.

1915-1916 Two 12-inch mortar batteries (Whistler and White) were constructed.

1916 159.40 acres of Navy land were transferred to the War Department, while 57.80 acres of the military reservation were transferred to the Naval Department by Executive Order Number 2328. During the disastrous (Hatfield) flood of 1916, Navy Radio Station Point Loma was San Diego's only serviceable communication link with the outside world.

1918 The guns of Battery Fetterman and Battery McGrath were dismantled and sent to Europe for use in World War I. The guns from Battery Mead on North Island were installed in Battery McGrath. Batteries Mead and Fetterman were abandoned at this time.

1920 All work recommended by the Taft Board had been completed. The improvements included Batteries White and Whistler, as well as a new system of searchlights and fire control stations.

1926 Charles J. Sullivan described Fort Rosecrans:

> *This post was established in 1904 and named in honor of General Rosecrans. It is one of the most beautiful posts in the Army. It is not likely to be occupied by more than a caretaking detachment for some time.*

1931 The government announced that it would abandon Fort Rosecrans along with several other military installations.

The plans to abandon Fort Rosecrans were fought by local Representative Phil D. Swing.

1932 **6 December**. The site of Fort Guijarros became California Registered Historical Landmark #69.

1933 The Cabrillo National Monument was turned over to the National Park Service, and the original Point Loma Lighthouse was restored.

1935 By the mid-1930s, the threat of war resulted in a renewed emphasis on coastal defense. It was announced in September that Fort Rosecrans would be strengthened. The fort was revitalized between 1936 and 1940.

1935 One commissioned officer and 20 buck privates comprised the entire standing army at the fort.

1935 Fort Rosecrans Post Cemetery, also referred to as Bennington Cemetery, became a National Cemetery.

1935 **7 March**. It was reported in the *Daily News* that, within the past year, six (Japanese) had been caught wandering about sketching and photographing.

> *The last one to be arrested, a few days before I arrived, was found to have a 250-page book, containing maps and descriptions of North Island, the Naval Training Station, the Marine Base, the harbor channel, and detailed drawings of the fort plan....*

1935-1963 Landfill activities occurred along the channel side of Point Loma.

1936 All coal in storage at the Naval Fuel Depot (formerly Naval Coaling Station) was declared unfit for Navy use and sold. In July, Battery White was practice-fired for the first time in 11 years.

1937 Construction of a new building and Battery Strong at Fort Rosecrans began.

1940 **October.** It was announced that the ranks of Fort Rosecrans would grow to 21,000.

1940 A new plan for the defense of San Diego Harbor was developed. The new plan consisted of a network of batteries and fire control facilities stretching along the coast from the International Border to Cardiff. Fort Rosecrans would remain central to the system. New armament planned for Fort Rosecrans consisted of two batteries of two 6-inch guns each (Batteries Humphrey and Woodward) and one battery of two 16-inch guns (Battery Ashburn).

1940 **1 June.** The Secretary of the Navy established the U.S. Navy Radio and Sound Laboratory.

1941 **26 April.** The University of California Division of War Research was established by the Office of Scientific Research and Development and assigned to joint operations with the U.S. Navy Radio and Sound Laboratory. Following the Japanese attack on Pearl Harbor on 7 December, Navy Radio Station Point Loma served as the main communication station of the entire Pacific Fleet for 60 hours due to problems sustained at the radio station at Pearl Harbor.

1942 **30 April.** The Navy Department acquired 60 acres of privately owned land north of the military reservation boundary for expansion of the Navy Radio and Sound Laboratory. The property was acquired through Civil Action 170-SD. In the

fall of 1942, Batteries Wilkenson, White, and Whistler were declared obsolete and abandoned. The Navy Small Craft Facility, as part of the Naval Operating Base, was established on Quarantine Station property.

1943 The Naval Fuel Depot was placed under the jurisdiction of the Naval Supply Depot and was redesignated the Fuel Annex. In July 1943, Battery Humphrey was completed. Battery Woodward was completed in November of the same year.

1944 **5 June.** The Navy Department acquired 55 acres of privately owned land adjoining the northern boundary of the property obtained in 1942. In July, Battery Ashburn was completed.

1945 **August.** The United States dropped two atomic bombs on Japan. By the end of the month, the San Diego Harbor Defense post had been closed. The war officially ended on 2 September. On 29 November, the name of the U.S. Navy Radio and Sound Laboratory was changed to the U.S. Navy Electronics Laboratory (NEL).

1946 **30 June.** The University of California Department of War Research was terminated. Most of the remaining projects were taken over by the U.S. Navy Electronics Laboratory.

1947 **4 August.** 11.4 acres of Fuel Facility lands and all structures of the Small Craft Facility were ordered transferred to the jurisdiction of the U.S. Navy Electronics Laboratory.

1949 **28 April.** The property of Navy Radio Station Point Loma was transferred to the U.S. Navy Electronics Laboratory by authority of the Secretary of the Navy. On 30 June, the Quarantine Station property was transferred from the Public Health Service to the U.S. Navy Electronics Laboratory.

1951 **26 February.** The Secretary of the Army transferred Areas One, Two, and Three of Fort Rosecrans to the Navy, resulting

in the placement of the Upper Cantonment, Model Range, Batteries Strong, Whistler, and Woodward, and all lands west of Catalina Boulevard and north of Monument 5 under the jurisdiction of the U.S. Navy Electronics Laboratory.

1951 **30 April**. The Naval Personnel Research Activity (Naval Personnel and Training Research Laboratory) was permitted occupancy in the NEL Barracks Area (Upper Cantonment Area).

1951 **23 July**. 241,000 acres of Fort Rosecrans Upper Cantonment Area were transferred to NEL. 135,000 additional acres were transferred from the Army to the Commander, Eleventh Naval District (COMELEVEN).

1952 Scripps Institution of Oceanography Visibility Laboratory was permitted occupancy in the NEL Barracks Area (permit later amended to a license including additional building use).

1952 **March.** Fleet Air Defense Training commenced in a new facility at the CIC School. The activity was later redesignated Fleet Anti-Air Warfare Training Center.

1954 The Fuel Annex pipeline to Naval Air Station, Miramar, was constructed with additional aviation gasoline storage constructed at the Fuel Annex.

1955 2.89 acres of Fort Rosecrans land were transferred to the Navy for the Deperming Station (an area north of the degaussing range for magnetic treatment of ships, but part of the Degaussing Station).

1956 **8 October.** 41.84 acres of Fort Rosecrans land were transferred to the Quartermaster General of the Army for expansion of the Fort Rosecrans National Cemetery.

1956 The Treasury Department permit to NEL for use of 2.5 acres of Point Loma Light Station land was reduced to 0.98 acre.

1957 **3 December.** All remaining Fort Rosecrans property containing approximately 595 acres was transferred to the Navy subject to further transfer of 14.5 acres from the Navy to the Department of the Treasury for Coast Guard Light Stations at Ballast Point (3 acres) and Point Loma (11.5 acres), and 80.60 acres from the Navy to the Department of the Interior for the Cabrillo National Monument.

1959 **1 March.** Fort Rosecrans property transferred to the Navy on 3 December 1957 was assigned to NEL for command and plant property responsibilities (495.97 acres).

1959 **12 March.** Fort Rosecrans, a Class I subinstallation of Fort MacArthur, California, was discontinued as an Army installation.

1959 **1 June.** The Navy Medical Neuropsychiatric Research Unit was established and permitted occupancy in the NEL Barracks Area.

1959 **1 July.** Of the 135 acres transferred from the Army in 1951, COMELEVEN permitted 7.80 acres at the northern end of Point Loma and 6.00 acres north of the Cabrillo Monument to be used by NEL for test and operating sites.

1959 **1 December.** COMELEVEN assigned the Navy Harbor Defense Unit site (4.25 acres, including Battery Humphrey) to NEL.

1959 **December.** The Naval Supply Depot Fuel Annex was redesignated the Naval Supply Center, Point Loma Annex.

1960 **11 April.** COMELEVEN assigned to NEL the remaining 130.75 acres transferred from the Army to the Navy (the two parcels permitted to NEL in 1951 were part of the 130.75 acres).

1960 **16 December.** NEL assigned a 42.85-acre site adjoining the Point Loma Station to the Department of the Interior for finite operation of a pilot saline-water conversion plant.

1961 **July.** The Fleet Computer Programming Center, Pacific, was established in a new facility at the Fleet Anti-Air Warfare Training Center.

1962 **1 March.** NEL transferred 6.70 acres of land for expansion of the Navy Degaussing Station.

1962 **13 April.** The Department of the Navy conveyed title to 37.60 acres of NEL land to the City of San Diego for the Metropolitan Sewage treatment plant.

1963 **1 July.** 341.20 acres, comprising the eastern Lower Cantonment Area, were transferred to temporary custody of the Navy Public Works Center pending establishment of the Navy Submarine Support Facility. From the 341.20-acre panel, 0.91 acre was transferred to Fort Rosecrans National Cemetery, and 4.37 acres were transferred to the Navy Degaussing Station.

1963 **October.** The Navy Submarine Support Facility was established. On the basis of a Real Estate Summary Map prepared by Southwest Division, BuDocks, 313.35 acres were reported as reassigned from the Public Works Center to the Navy Submarine Support Facility.

1963 **December.** The Fleet Anti-Submarine Warfare School was permitted use of a portion of NEL Building 15 and the adjacent area for a passive sonar training facility.

1964 The Quarantine Station permit was terminated, and the Quarantine Office Building 121 was converted to NEL use.

1964 **1 March.** The Navy leased the 5.80 acres acquired from the Quarantine Station to the University of California for 25 years for installation and operation of the Nimitz Ship Operating Facility.

1966 **20 June.** The Navy transferred 3.27 acres of Fleet Anti-Air Warfare Training Center land at the north boundary to the United States International University (Cal Western).

1966 **1 September.** The Naval Station Target Repair Base was disestablished. A 0.82-acre parcel was reassigned to NEL, and 3.12 acres were reassigned to the Public Works Center (PWC).

1967 Under the 1967 Navy laboratories reorganization, the title of the Navy Electronics Laboratory was changed to the Naval Command Control and Communications Laboratory Center (NCCCLC), with the undersea research and development technology transferred to the newly established Naval Undersea Warfare Center (NUWC).

1968 **13 April.** The name of the Naval Command Control Communications Laboratory Center was changed to the Naval Electronics Laboratory Center (NELC).

1968 **1 July.** The Chief of Naval Material directed relocation of NUWC headquarters from Pasadena to San Diego. The NUWC title was soon changed to the Naval Undersea Research and Development Center (NURDC) and later changed to the Naval Undersea Center (NUC).

1969 **1 March.** NELC transferred 35.23 acres of property to NUWC, including 22.60 acres in the Waterfront area, 0.82 acre formerly part of the Target Repair Base, the 5.45-acre Arctic Research Complex, the 5.55-acre TRANSDEC Facility, and the 0.81-acre salt water intake facility for the Arctic Research Complex.

1969 The Public Works Center transferred 3.12 acres, the remaining area of the former Target Repair Base, to the Naval Undersea Research and Development Center.

1969 **1 September.** NELC reassigned the former Army radio station, Building 558, and the 1.00 acre of land on which it is situated, to the Navy Submarine Support Facility.

1970 **14 August.** The Department of the Interior returned the 42.85-acre saline-water conversion plant site to NELC. The Navy transferred 6.88 acres of Submarine Support Facility land (adjoining the north boundary of the Cabrillo National Monument and the east side of State Highway 209) to the Department of the Interior for a maintenance facility site.

1974 **28 September.** By Presidential Proclamation 4319 of 28 September 1974, 56.26 acres of Navy land (NELC—37.64 acres, SUBSUPFAC—18.62 acres) were transferred to the Department of the Interior for annexation to the Cabrillo National Monument.

1977 **1 March.** Property of NELC and NUC was combined under a consolidation to form the Naval Ocean Systems Center (NOSC).

Letters of Congratulations

THE ASSISTANT SECRETARY OF THE NAVY
(Research, Development and Acquisition)
WASHINGTON, D.C. 20350-1000

MAY 25 1990

MEMORANDUM FOR COMMANDER, NAVAL OCEAN SYSTEMS CENTER

Subj: NAVAL OCEAN SYSTEM CENTER (NOSC) 50TH ANNIVERSARY

Congratulations on this significant event in the history of the Naval Ocean Systems Center--the 50th Anniversary of your establishment as the Navy's first West Coast research laboratory. Since the establishment of the U.S. Navy Radio and Sound Laboratory on 1 June 1940, your Center has conducted research with important applications to Navy developmental systems. Beginning with World War II research that contributed substantially to development of more effective sonars, radars and communications systems, your Center has pioneered a number of scientific advances leading to breakthroughs in areas related to your mission.

Areas of concentration for your researchers have included hydrodynamics, including drag reduction aimed at increasing the effectiveness of torpedoes; propagation of acoustic and electromagnetic energy, specifically underwater acoustics related to undersea surveillance and atmospheric propagation with applications to communications; oceanographic studies, including currents, temperature, salinity, marine organisms and structure of the sea floor; study of the formation and structure of sea ice in the Arctic and acoustic propagation under the ice to improve Navy ASW capabilities in this critical area of the globe.

Your laboratory can take significant pride in the pioneering work accomplished in development and application of automatic data processing techniques to command and control system design and evaluation, and to simulation for weapons testing. NOSC-developed environmental assessment systems provide capabilities in two substantially different fields--atmospheric propagation of electromagnetic energy leading to performance prediction techniques for high frequency communications and electronic warfare systems, and capabilities for real-time monitoring of water quality to ensure the Navy maintains a responsible attitude toward the environment in which it operates its ships and submarines.

In such diverse areas as marine mammals and microelectronics, data display technology and astro-geophysics, chemical oceanography and optical fiber technology, NOSC and its predecessor laboratories have studied the principles of science and employed that knowledge for the improvement of Navy operations systems. Several programs stand out amidst the multitude of technological developments in which your laboratory can take exceptional pride:

Testing of the Navy's first operational radar set;

Coordination of the descent of the bathyscaphe Trieste to the deepest known depth in the ocean--35,800 feet in the Challenger Deep of the Marianas Trench;

Development of the first liquid laser to produce a visible light beam;

Design and fabrication of the first unmanned undersea vehicle (UUV) and successful employment of that vehicle to recover a hydrogen bomb from the floor of the Mediterranean Sea;

Use of a later model UUV in rescuing two men trapped in the Pisces III submersible on the bottom of the Irish Sea;

Location of the wreckage of the sunken submarine USS THRESHER; and

Technical direction of the submerged transpolar crossing of USS NAUTILUS and the first surfacing of the North Pole of USS SKATE.

The innovation that has characterized the efforts of your laboratory is nowhere more evident than in the remarkable record of patents issued to NOSC personnel. Center management has taken a strong position in emphasizing the importance of patents, resulting in filing of 407 applications in the last ten years and a position of leadership in this area among the Navy's major R&D centers. Similarly, the number and quality of technical publications by your Center attests to the significance of your research efforts.

As earlier technology base programs pursued by your laboratory have paid significant dividends for our operational forces afloat today, so your ongoing research holds the promise of similar impact on tomorrow's Navy. In the area of ocean surveillance, the High Gain Initiative promises revolutionary improvements in our ability to detect quieter submarines. Air and spaceborne optical communication systems, as exemplified by the Tactical Airborne Laser Communications program, could provide real-time connectivity to our submarine forces, ensuring a fully coordinated force capability. Additionally, your substantial efforts in a number of new and exciting emerging technology areas, such as artificial neural networks, superconcurrency computing, and ultra-wideband radars, will ensure the Navy's full understanding and appreciation of the potential benefits which these developments hold.

Once again, please accept my warmest congratulations on the scientific accomplishments of your laboratory, and on the occasion of your in-house ceremony on 31 May, please convey my thanks and best wishes to the talented and creative personnel of your organization.

Gerald A. Cann

Gerald A. Cann

DEPARTMENT OF THE NAVY
SPACE AND NAVAL WARFARE SYSTEMS COMMAND
WASHINGTON, D.C. 20363-5100

IN REPLY REFER TO:
1 June 1990

From: Commander, Space and Naval Warfare Systems Command
To: Commander, Naval Ocean Systems Center

Subj: NAVAL OCEAN SYSTEMS CENTER 50TH ANNIVERSARY

1. Please accept my sincere congratulations on the occasion of the 50th Anniversary of the Naval Ocean Systems Center. Since its establishment on 1 June 1940 as the U.S. Navy Radio and Sound Laboratory, the Center has diligently pursued scientific and engineering programs of unsurpassed excellence. The significant contributions of your Center to the United States Navy date back to World War II, when the two organizations that eventually would form the present-day laboratory provided submarine decoy devices, sonars, navigation beacons and torpedoes to the war effort. The Mark 13 torpedoes modified by one of your predecessor laboratories played a major role in the decisive Navy victory at the Battle of Leyte Gulf, while the QLA FM high definition sonar developed by the other laboratory allowed U.S. submarines to penetrate the heavily mined Japanese Inland Sea and effectively sever communications between the five main Japanese islands.

2. During succeeding years, one laboratory organization pursued development of electronic systems for command and control, communications, navigation and sonar, while the other developed weapon systems, principally antisubmarine torpedoes. In an effort termed by the Navy Operations Handbook of the Day as something from "the realm of fantasy," the electronics laboratory developed equipment and techniques to allow submarine operation under the Arctic ice cap. This early effort eventually would provide the U.S. Navy a critical advantage in this important area of the world. The following decades saw substantial contributions to the fleet in the major areas of electronics and weapons development, as well as peripheral programs resulting in such wide-ranging successes as the bathyscaph Trieste descent to 35,800 feet in the Marianas Trench; the undersea living experiments with the Sealab habitats; support of the Apollo and Space Shuttle space programs; hydrodynamic and physiology studies of bottlenose dolphins; and astro-geophysical research related to acoustic propagation and ionospheric forecasting.

3. The two laboratory organizations contributed in a quiet but significant fashion to the campaigns in Southeast Asia through the Vietnam Laboratory Assistance program. The Center continues to play a leading role in the outgrowth of that effort, the Navy Science Assistance program.

4. By the early 1970s, the weapons development program of what was then the Naval Undersea Center had moved to San Diego, where that Center maintained complementary programs in undersea surveillance, marine science and ocean engineering. Its facilities were located within sight of the Naval Electronics Laboratory Center, which pursued programs in aerospace surveillance in addition to the main product areas of command and control and communications. With an eye to the synergism of combined programs in surveillance, C3 and ASW, the laboratories were consolidated in 1977 to form Naval Ocean Systems Center.

5. Since that consolidation, your laboratory has achieved a remarkable record of success in bringing its resources to bear on what the Chief of Naval Operations has called "the most difficult task in modern warfare" and his "primary war fighting concern"--ASW. In 1980, Center engineers guided the Surveillance Towed Array Sensor (SURTASS) system successfully through technical and operational evaluation on its way to installation aboard the Navy's new STALWART class of surveillance ships. The Vertical Launch Antisubmarine Rocket, carrying the Center-developed Mark 46 torpedo, will provide the Navy's Vertical Launch System-equipped surface ships with ASW stand off capability. The Center's full-spectrum approach to ASW provides, in one laboratory, expertise in and development support of tactical and strategic undersea surveillance systems, ASW fire control systems and ASW weapons. Your laboratory continues its active research in the Arctic to ensure ASW coverage in that strategically important area of the world.

6. The Center also enjoys a remarkable record of success in the areas of command and control, communications and intelligence (C3I). Our modern satellite communications systems are based on concepts formulated and developed by your laboratory. The Navy's emerging command and control capabilities, both afloat and ashore, are based largely on systems developed at Naval Ocean Systems Center. While the Center-developed Naval Tactical Data Systems remains, after almost three decades, the standard Navy shipboard C2 system, new programs focusing on development of the Tactical Flag Command Center and the integration of the Joint Tactical Information Distribution System, the Command and Control Processor, and the Advanced Combat Direction System give promise of an order to magnitude improvement in command and control capabilities.

7. The system hardware and software developments nearing fleet introduction today are backed by bold new initiatives in a variety of technology base areas, many of which promise substantial dividends for Navy programs of the future.

8. During the change of command ceremony last October, I emphasized the essential role played by the people of your laboratory in developing the systems the Navy will require in the decades to come. Please accept my sincere appreciation for your efforts as Commander, those of your Technical Director, and to all of the Center management for their superb leadership and technical achievements.

9. Thank you for the invitation to your 50th Anniversary dinner in July. I hope to be able to attend. In the meantime, please accept my sincere best wishes and congratulations on your 50 years of outstanding contribution to the Navy and the Nation. I look for even greater accomplishments during the next 50 years.

John C. Weaver

JOHN C. WEAVER
Rear Admiral, U.S. Navy

Glossary

A

ACDS	Advanced Combat Direction System
AFB	Air Force Base
AG	Miscellaneous (ship classification)
APEX	Arctic Pulsed Experimental (sonar)
ARC	Acoustic Research Center
ASDEC	Applied Systems Development and Evaluation Center
ASL	Arctic Submarine Laboratory
ASR	Antisubmarine Rocket
ASROC	Antisubmarine Rocket
ASW	Antisubmarine Warfare
ASWCS	ASW Control System
ASWSCCS	ASW Ship Command Control System
ATV	Advanced Tethered Vehicle

B

BuAir	Bureau of Aeronautics
BuDocks	Bureau of Yards and Docks
BuMed	Bureau of Medicine and Surgery
BuOrd	Bureau of Ordnance
BuPers	Bureau of Naval Personnel
BuSandA	Bureau of Supplies and Accounts
BuShips	Bureau of Ships
BuWeps	Bureau of Naval Weapons

C

C^3	Command, Control, and Communications
C^3 SITE	C^3 Systems Integration Test and Evaluation
Caltech	California Institute of Technology
CC	Command Ship
CDS	Coordinated Display System
CG	Guided Missile Cruiser
CLG	Guided Missile Light Cruiser
CNM	Chief of Naval Material
CNO	Chief of Naval Operations
CNR	Chief of Naval Research
CO	Commanding Officer
CRT	Cathode-Ray Tube
CSDS	Command Ship Data System
CURV	Cable-Controlled Underwater Recovery Vehicle
CV	Aircraft Carrier
CVS	ASW Aircraft Carrier

D

DARPA	Defense Advanced Research Projects Agency
DNL	Director of Navy Laboratories
DoD	Department of Defense
DSSP	Deep Submergence Systems Project

E

EDATL	Electronics Development and Test Laboratory
EVS	Enhanced Verdin System

F

FCG	Fire Control Group
FCS	Fire Control System
FDDS	Flag Data Display System
FFDS	Fleet Flag Data System
FLTSATCOM	Fleet Satellite Communications
FORACS	Fleet Operational Readiness Accuracy Check Sites

G

GNP	Gross National Product
GTR	General Tire and Rubber

I

IBGTT	Interim Battle Group Tactical Trainer
IED	Independent Exploratory Development
IFDS	Integrated Flagship Data System
IFF	Identification Friend or Foe

IREPS	Integrated Refractive Effects Prediction System
ISABPS	Integrated Submarine Automated Broadcast Processing System
ISAR	Inverse Synthetic Aperture Radar
IXS	Information Exchange System

L

LAMBDA	Large Aperture Marine Basic Data Array (system)
LAMPS	Light Airborne Multipurpose System
LF	Low Frequency
LPH	Amphibious Assault Ship

M

MCM	Mine Countermeasures Ship
MEQA	Marine Environmental Quality Assessment (program)
MESC	Marine Environmental Survey Craft
MNS	Mine Neutralization System
MOSS	Mobile Submarine Simulator
MPDS	Message Processing and Distribution System
MPL	Marine Physical Laboratory
MTWS	Marine air-ground task force Tactical Warfare Simulation

N

NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVMAT	Naval Material Command
NAVSHIPS	Naval Ships Systems Command
NCCCLC	Naval Command Control and Communications Laboratory Center
NDRC	National Defense Research Committee
NEARTIP	Near Term Improvement Program
NEL	U.S. Navy Electronics Laboratory
NELC	Naval Electronics Laboratory Center
NEWS	Navy Electronic Warfare Simulator
NIF	Navy Industrial Fund
NOL	Naval Ordnance Laboratory
NORDA	Naval Ocean Research and Development Activity
NOSC	Naval Ocean Systems Center
NOTS	Naval Ordnance Test Station
NPRDC	Navy Personnel Research and Development Center
NRAC	Naval Research Advisory Committee
NRL	Naval Research Laboratory
NRSL	U.S. Navy Radio and Sound Laboratory
NSAP	Navy Science Assistance Program
NTDS	Navy Tactical Data System
NUC	Naval Undersea Center
NURDC	Naval Undersea Research and Development Center
NUWC	Naval Undersea Warfare Center
NWC	Naval Weapons Center

O

ONR	Office of Naval Research
ONT	Office of Naval Technology
OSD	Office of the Secretary of Defense
OSRD	Office of Scientific Research and Development
OTH	Over-the-Horizon

R

R&D	Research and Development
RAT	Rocket Assisted Torpedo
RDT&E	Research, Development, Test, and Evaluation
RESA	Research, Evaluation, and Systems Analysis (system)
RF	Radio Frequency
RFI	Radio Frequency Interference
ROV	Remotely Operated Vehicles
RUWS	Remote Unmanned Work System

S

SAR	Synthetic Aperture Radar
SCP	Secure Conferencing Project
SECNAV	Secretary of the Navy
SHF	Super High Frequency

	SLC	Satellite Laser Communication
	SOFAR	Sound Fixing and Ranging (system)
	SOSUS	Sound Surveillance Underwater System
	SPAWAR	Space and Naval Warfare Systems Command
	SPECTRA	Special Transmissions (sonar)
	SS	Submarine
	SSBN	Fleet Ballistic Missile Submarine (nuclear propulsion)
	SSCDS	Small Ship Combat Data System
	SSIXS	Submarine Satellite Information Exchange System
	SSN	Submarine (nuclear propulsion)
	STIC	Surveillance Test and Integration Center
	SUBROC	Submarine Rocket
	SURTASS	Surveillance Towed Array Sensor System
	SWATH	Small-Waterplane-Area Twin Hull
	SYSCOM	Systems Command
T	T-AGOS	Ocean Surveillance Ship
	TD	Technical Director
	TECHEVAL	Technical Evaluation
	TFCC	Tactical Flag Command Center
	TRANSDEC	Transducer Evaluation Center
	TWAES	Tactical Warfare Analysis and Evaluation System
	TWSEAS	Tactical Warfare Simulation, Evaluation, and Analysis System
U	UCDWR	University of California Division of War Research
	UCLA	University of California at Los Angeles
	UCSD	University of California at San Diego
	UDT	Underwater Demolition Team
	USNR	U.S. Naval Reserve
	USNS	United States Naval Ship
	USS	United States Ship
	UUV	Unmanned, Undersea Vehicle
V	VAL	Variable-Angle Launcher
	VAT	Variable Atmosphere Tank
	VLA	Vertical Launch ASROC
	VLAP	Vietnam Laboratory Assistance Program
	VLF	Very Low Frequency
	VLS	Vertical Launching System
W	WARS	Warfare Analysis and Review System
	WES	Warfare Environment Simulator
	WSA&E	Warfare Systems Architecture and Engineering

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